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A Look at
COMMERCIAL RECREATION
on Small Woodlands in Ohio

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A Look at
COMMERCIAL RECREATION
on Small Woodlands in Ohio

SMALL PRIVATE WOODLANDS can be used profitably for commercial recreation enterprises. Study of five recreation developments in Ohio provides a guide to what the investor must consider in undertaking such an enterprise.

Use of small private woodlands for recreation has been encouraged. The Outdoor Recreation Resources Review Commission in its 1962 report, *Outdoor Recreation for America,* recommended to the President and the Congress that efforts be made to stimulate commercial investment in diversified recreational enterprises on private lands and waters.

Many small private woodlands in the heavily populated eastern United States are ripe for such investments. However, the investor considering such an undertaking has very little information to guide him. Among other things, he needs to know what types of activities complement and compete with each other, how much to charge users for the activities that he might offer, whether to develop his enterprise fully at once or gradually, what restrictions he should impose upon users for their enjoyment and safety, and how much capital investment he will need, and what income he might realize from such a business venture.

To provide some answers to these questions, we studied the establishing and operation of five diversified outdoor recreation enterprises in Ohio in 1964. Our objectives were to determine: (1) how such businesses evolved, (2) the capital investment incurred, (3) the methods used to finance development, (4) the problems encountered during development, (5) changes the owners would make if developing their businesses again, (6) operating policies followed, (7) season and hours of operation, (8) fee systems employed, (9) promotional methods used, (10) and annual income and expenses.

Although each recreation enterprise selected for this study offered two or more major activities to its patrons, primary attractions were:

Enterprise No.	*Primary attraction*
1	Camping
2	Swimming
3	Private parties
4	Fishing
5	Skiing

Information about these enterprises was obtained from interviews with the owners or principal operators. Respondents freely answered most of the questions asked. All were hesitant about revealing income and expense information, but only one respondent withheld information even though he was assured that all figures would be kept in strict confidence. Two other respondents gave only general estimates of specific expense items.

FACILITIES

Natural resources at each enterprise included a woodland and either a lake or stream (table 1). Other types of land included open pasture and idle cropland. All enterprises functioned on 150 acres or less.

Besides its primary attraction, each enterprise provided activities that could be used by all age groups (figs. 1 and 2). Where the water resource was adequate, facilities for boating, fishing, and swimming were provided (figs. 3 and 4). Some facilities for

Figure 1.—Horseback riding is a popular activity at commercial recreation enterprises in Ohio.

picnicking were provided or planned at every location studied. All operators sold prepared food or grocery items to their patrons. Those operators who were not providing some camping facilities were planning to do so (fig. 5).

All but one enterprise was accessible by hard-surface roads, and the operator of this one had petitioned his county highway department to improve his road. Each enterprise was situated no more than a 3-hour drive from a metropolitan area of 500,000 or more people. Most operators seemed more concerned to attract nearby residents than people from distant localities.

Capacity may be expressed several ways at recreation enterprises—number of campsites, boats, picnic tables, horses, or acres —but the number of users that can be accommodated daily

Table 1.—*Natural resources at each enterprise*

Enterprise No.	Primary attraction	Resource		
		Woodland	Water	Other[1]
		Acres	*Acres*	*Acres*
1	Camping	98	20	—
2	Swimming	60	6	—
3	Parties	30	([2])	20
4	Fishing	133	17	—
5	Skiing	60	([2])	—

[1] Includes open pasture and idle cropland.
[2] Stream.

Figure 2.—Skiing has become popular in Ohio.

serves as a reasonable basis for comparison. Using such a measure, we estimated capacity at 500 to 7,500 users at the five enterprises (table 2).

Three of the five operators planned to add facilities to increase capacity as quickly as possible. One enterprise was being put up for sale because its owner wanted to retire, and the other was undergoing a complete reorganization because one of its owners had gone bankrupt through outside investments.

ENTERPRISE DEVELOPMENT

Though all five operators said desire for profit was their main reason for going into business, two of the five said they began their enterprises for personal recreation. These two both gave the following reasons for changing to a commercial business: (1) the desire to recover the large expenses entailed in developing their enterprises, and (2) acquired knowledge of public demand for outdoor recreation. Two of the other enterprises began as much smaller, single-activity businesses. They evolved into diversified commercial recreation enterprises because demand outgrew capacity and patrons asked for additional facilities and services.

Table 2.—*Daily capacity at each enterprise, in number of patrons participating*

Enterprise No.	Primary attraction	Capacity
1	Camping	1,800
2	Swimming	4,000
3	Parties	7,500
4	Fishing	500
5	Skiing	1,500

All five operators had developed enterprises gradually: only two had planned for it. Four said that development depended on building up capital from operating profits or personal savings. Most said they could not obtain outside capital for anything other than purchasing land. So the old problem of limited funds may have been the primary hindrance to more rapid development.

Capital investments for these enterprises ranged from $36,000 to $380,000. Land and property improvements (pond or lake construction, road-building, clearing, grading) accounted for most of the cost (table 3). The many hours of labor contributed by the owners are not included in these figures. For example, one owner-operator and his family spent most of their weekends and

Figure 3.—Boats are available for anglers at many commercial recreation enterprises.

Figure 4.—Well developed swimming areas are important for commercial recreation enterprises.

vacation time during a 2-year period developing their business. Other owners had likewise made large contributions of their time. Willingness to put in many long hard days of work is apparently one requirement for any would-be operator in this field.

Every operator reported that he would have developed his enterprise differently if he could do it again. One said he would have bought more land initially. At a later date he was trying to acquire adjacent land but by then had to pay far more than he would have had to in the beginning.

Another said he would begin with the most modern facilities available instead of trying to get along with merely adequate ones.

The operator of the enterprise where fishing was the primary activity said he would build a smaller lake with a more regular shoreline. Policing the area and cleaning up litter cost too much with the larger lake.

Table 3.—*Capital investment and share of total for various assets at each enterprise*

Item	Enterprise and primary attraction				
	1 Camping	2 Swimming	3 Parties	4 Fishing	5 Skiing
apital investment	$36,000	$154,000	$110,500	$206,500	$380,000
hare for:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Land	22.9	9.7	45.2[1]	54.5	19.7
Land improvement	52.8	44.8	—	14.5	17.9
Buildings	6.9	35.4	36.2	22.8	22.9
Equipment	16.3	9.7	18.1	8.0	32.9
Annual inventory	1.1	.4	.5	.2	6.6

[1] Includes land improvements.

One operator said he would have developed more facilities for daily patrons than for overnight guests if he had an opportunity to begin again. He said he would locate facilities differently to avoid traffic congestion and would establish more thorough fee systems whereby patrons would pay only for those facilities they used.

Two operators said they would make use of professional advertising agencies to build up attendance earlier than they had. And four said they would devote more time to training employees.

Figure 5.—Facilities for camping were available or were being planned at all enterprises.

OPERATION

The primary operating policy at all five enterprises was to provide customers with the highest quality of recreation possible. Closely associated with this was a policy of maximum cleanliness. All operators were very strict about the appearance of both employees and facilities. It was common for operators to have picnic tables scrubbed with soap and water at the end of each day, to have toilets thoroughly cleaned during and after each day of operation, and to have at least one person constantly policing the area for unsightly litter. One operator repainted all facilities before opening for business each spring.

Two operators prohibited drinking of alcoholic beverages on their premises and the other three permitted drinking only in moderation. All five operators admitted that they had been unable to prevent people from drinking, but all said that they believed they had prevented drinking from hurting their businesses.

None of the operators posted do's and don'ts; each said that he maintained only those regulations necessary for the customers' enjoyment, convenience, and safety. This idea was to make a patron feel unrestricted while using the facilities provided.

The season and hours of operation varied, depending on the primary attraction (table 4). Two enterprises were open year-round but had most of their business during certain seasons.

Three of the operators used a system of separate fees for each facility used; two charged users a general admission. Two of those using the separate fee system and one using the general admission system offered annual memberships or season tickets. One type of season ticket permitted its holders to use facilities

Table 4.—*Season and hours of operation at each enterprise*

Enterprise No.	Primary attraction	Season	Hours open	
			Weekdays	Weekends
1	Camping	All year	7 a.m.-10 p.m.	7 a.m.-10 p.m.
2	Swimming	Jun.-Aug.	10 a.m.- 7 p.m.	10 a.m.- 7 p.m.
3	Parties	All year	9 a.m.-12 m.	9 a.m.-12 m.
4	Fishing	Mar.-Oct.	6 a.m.- 9 a.m.	4 a.m.-12 m.
5	Skiing	Dec.-Mar.	10 a.m.-10 p.m.	9 a.m.-11 p.m.

at a lower rate than non-holders and the other type permitted unlimited use of all facilities at no additional cost. The following fees were charged for selected activities:

Activity	*Fees*
Family camping (4 persons)	$1.25 - $1.65 per day (or $15.00 per month)
Fishing (1 person—limited take)	$0.50 - $1.50 per day
Swimming (adults)	$0.30 - $0.50 per day
Swimming (children)	$0.20 - $0.50 per day
Boating (boat rented)	$0.50 - $1.00 per hour (or $3.00 per day)
Boating (own furnished)	$0.50 per day
Picnicking (per table)	$0.50 per day
Horseback riding	$1.75 - $2.00 per hour
Pony ride	$0.25 per ride
Skiing (adults)	$2.50 - $5.50 per day
Skiing (children)	$1.25 - $2.75 per day
Private party (under 250 people)	$100.00 per day
Private party ((251-500 people)	$200.00 per day
Private party (501-750 people)	$300.00 per day
Private party (over 750 people)	$400.00 per day
Riding lessons	$2.00 - $3.50 per hour
Skiing lessons	$2.00 - $8.00 per lesson

Most fees were set at what the operator considered the going rate for such activities. Rates for camping and skiing were higher where fuel, electricity, and equipment were provided by the operator.

All five operators employed one or more persons full time during the major season of operation (table 5). All employed one or more extra workers on weekends and holidays. Many of those employed were high school and college students; a few older persons held some of the jobs to supplement their principal source of income.

Table 5.—*Employment at each enterprise during usual operation*

Enterprise No.	Primary attraction	Number employed	
		Weekdays	Weekends
1	Camping	2	3
2	Swimming	13	18
3	Parties	4	6
4	Fishing	1	4
5	Skiing	15	25

All operators were advertising or had advertised to stimulate business. Three reported using spot commercials over radio; two had used a professional advertising agency; two had placed advertisements in Sunday newspapers in large Ohio cities; one had used brochures; and one had sent annual newsletters to previous customers.

One operator said he had been fortunate in having a feature article about his place published in a Sunday magazine section of a large city newspaper. He felt that this had stimulated attendance significantly. All operators agreed that a satisfied customer was their most effective promotion agent.

All operators said they were able to purchase adequate liability insurance at a reasonable rate. However, few would disclose either how much protection they had or how much it cost them annually.

The operators said they had few operating problems. In their early years of development, some had trouble with littering and vandalism, but they no longer considered these as serious problems. One operator said he had found it difficult to recruit reliable seasonal employees, but did not seem worried about future recruiting.

Four operators provided information about income and expenses. Two reported both income and expenses in dollars, from which we could estimate profit margins. One disclosed only gross receipts, and the other only a percentage summary of both income and expenses. These last two operators reported making a fair return.

From the income data supplied, supplemented by attendance and fee information, we estimated 1963 gross receipts at the five enterprises as follows:

Enterprise No.	*Gross receipts*
1	$ 8,000
2	85,000
3	62,000
4	32,500
5	145,000

Most of these enterprises enjoyed an increase in gross receipts over the years. For enterprise 1, 1963 was the first year of opera-

tion; and it seems likely that receipts from this enterprise may well have doubled or tripled over the next 2 or 3 years.

Depreciation, amortization, and supplies accounted for 35 to 81 percent of the total expenses at three of the five enterprises. (The other two did not provide usable information about these items.) For the three enterprises, total expenses on the indicated items ranged from $3,160 to an estimated $45,500 in 1963. Labor expenses varied from 19 to 40 percent of the total, depending on the need for close supervision at particular activities. Expenses incurred for fuel, water, and electric utilities accounted for only a small part of total costs.

CONCLUSIONS

Small private woodlands can be used for diversified commercial recreation. However, a recreation enterprise is a complex and costly undertaking. It is not something that anyone with natural resources and money should get into. Also, it is not the sort of business that is likely to satisfy anyone who wants quick profits from his investment.

Although investors put their money into commercial recreation enterprises to make profits, their desire to satisfy people's need for outdoor fun and relaxation is an important motive.

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Methods for Handling BLACK CHERRY SEED

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by Harold J. Huntzinger

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Methods for Handling BLACK CHERRY SEED

THE METHODS used in handling black cherry (*Prunus serotina* Ehrh.) seed after it has been collected will affect the percentage of germination obtained. Studies made at our Laboratory at Warren, Pa., have shown that good germination can be obtained when the seed is properly handled and stratified.

This publication reports the results obtained from three separate seed-handling studies. The various operations involved in handling black cherry seed are also discussed.

SEED-HANDLING STUDIES

The first study involved 21 combinations of methods for handling freshly collected seed. The second dealt with the effects of pre-stratification storage methods and chemical treatments on fresh seed. The third dealt with stratification time and chemical treatments on 1-year-old seed after storage at room temperature or in a household refrigerator. Germination was the dependent variable in all three studies.

Germination percentages, after transformation to the arc-sine, were subjected to analysis of variance. Orthogonal comparisons among treatments were then made. Germination values, based on speed of germination in conjunction with total germination, were determined by the method described by Czabator (*2*).

Study 1

The first black cherry seed-handling study was made in 1963 to determine how germination is affected, if at all, by: (1) removal of pulp when the fruits were collected, (2) drying the seeds or fruits before stratification, (3) collecting fruits before fully ripe (still green), and (4) method of stratification.

Black cherry fruits were collected from standing mature forest trees and from trees felled on logging jobs. Some seed that had been depulped and dropped by birds was collected from the ground in the immediate vicinity of growing trees. Most of this seed had been regurgitated by the feeding birds, rather than voided in their droppings.

The fruits and seeds were handled by seven different methods, all but the last involving fully ripened seed:

- Pulp removed and seed stratified without drying (except evaporation of surface moisture).
- Pulp removed, seed spread and dried for 15 days in a ventilated garage left open to the varying outdoor temperatures of early autumn, then stratified.
- Pulp removed; seed dried 30 days then stratified.
- Pulp not removed; intact fruits stratified without drying.
- Pulp not removed; fruits dried 30 days then stratified.
- Bird-dropped seeds collected daily, held temporarily in sealed glass jar, then stratified.
- Green fruits, collected in late August, stratified intact without drying.

Several variations of the stratification treatment were compared: outdoor versus refrigerator, and sand versus peat media. Both media were used in the outdoor series but only peat in the refrigerated series. Four replicates of 100 seeds each were subjected to each of the 21 treatment combinations.

For the outdoor stratification, small wooden frames (12 by 12 by 4 inches) with screen wire tops and bottoms were used. Two layers of seed were placed between layers of the medium

in each frame. The loaded frames were placed in a shallow trench having a 6-inch gravel-sand base for drainage. The frame tops were about flush with the soil surface. After being placed in the trench, the frames were covered with hardwood leaves.

For the refrigerated stratification, a measure of seed was mixed with about four times its volume of peat in a small polyethylene bag. Bags were sealed with rubber bands. Temperatures ranged from 33° to 39° F.

Stratification periods ranged from 156 to 180 days for seeds or fruits that had undergone a drying treatment, and from 186 to 205 days for those that were stratified without predrying. Different starting dates accounted for some of the variation in stratification periods; another factor was that the refrigerator stratification was terminated earlier than the outdoor stratification.

Germination was determined in sand flats under day-night temperatures alternating between about 74° and 57° F. Seeds that germinated were tallied and removed twice a week for 4 weeks, and at weekly intervals thereafter. When no further germination was obtained for 7 days after the last count, the ungerminated seeds were cut and examined. These examinations showed that 95 percent of the 8,400 seeds used in the study were sound. Germination percentages and values for each of the seven seed-handling methods and each of the three stratification methods are shown in table 1.

Statistical analysis of the germination data showed significant differences at the 1-percent level among the 21 treatments. The main treatment effects were:

Stratification of ripe depulped seed without predrying (treatment 1) resulted in the most consistently high germination across all stratification regimes.

Leaving the pulp on the seed reduced germination. In treatment 4, which was identical with treatment 1 except for the pulp factor, germination after outdoor sand stratification was 67 percent, as compared with 91 percent for depulped seed. After outdoor peat stratification it was 82 percent, as compared with 86 percent. And after refrigerated peat stratification it was 8 percent, as compared with 88 percent.

Table 1.—*Percentages and germination values of fresh black cherry seed*

Pre-stratification treatment number	Outdoor stratification				Refrigerator stratification in peat	
	In sand		In peat			
	Total germination, percent	Germination value[1]	Total germination, percent	Germination value	Total germination, percent	Germination value
1	91	12.0	86	9.2	88	12.2
2	60	3.2	74	5.8	12	.2
3	41	1.4	31	.8	0	—
4	67	3.3	82	10.0	8	.01
5	34	.9	62	4.6	0	—
6	38	1.2	89	8.5	88	10.4
7	51	1.6	86	6.0	26	.3

[1]Germination value determined by method described by Felix J. Czabator in *Forest Sci.* 8 (4): 386-396.

Drying the seed before stratification also reduced germination, and 30 days' drying caused greater reduction than 15 days' drying: compare treatments 2 and 3 (table 1) with each other and with treatment 1; also treatment 5 with treatment 4.

At the stage of immaturity exemplified by the green fruits used in this study, the seed compared favorably in germination with the seed of ripe fruits—treatment 7 versus treatment 4.

Peat was superior to sand as a medium for outdoor stratification. We cannot explain the erratic results with peat stratification in the refrigerator.

Study II

In 1964, a study was made to determine the effects of prestratification temperature, moisture, and chemical treatments on seed germination. The effects were observed in stratification at weekly intervals from the 90th to the 120th day, and in germination flats after 120 days of stratification.

Fresh seed, collected in September 1963, was cleaned of pulp by mashing under a stream of cold water on October 4. After draining and thorough mixing, four samples of the seed were drawn for the prestratification or storage phase of the study. One sample was stored in a sealed polyethylene bag under each of these conditions: moist-cold, moist-warm, dry-cold, and dry-warm. For the moist storage, the seeds were thoroughly rewetted and then briefly drained before sealing in the bags; for the dry storage, the seeds were air-dried about 4 hours to remove all surface moisture before placing in the bags. All bags were sealed with rubber bands. An office cabinet in a room maintained at about 72° F. served for the warm storage; a refrigerator, which provided temperatures of 34° to 38° F., was used for cold storage.

On January 22, 4 months before sowing, the stored seed was treated by five different methods, stratified in peat, and placed in the refrigerator. The five treatments were:

- No chemical treatment.
- Soaked in a 3-percent hydrogen peroxide solution for 48 hours.

- Soaked in a 1-percent citric acid solution for 48 hours.
- Soaked in a 100-ppm. solution of gibberellin for 24 hours.
- Stratified untreated for 90 days, then (on April 21) soaked in a 100-ppm. solution of gibberellin for 2 hours, followed by 30 days' additional stratification.

After 90 days of stratification the seeds were examined weekly and a tally was made of the number of seeds that had broken dormancy (table 2). Seeds were considered to have broken dormancy when the radicle protruded beyond the seed coat. After 120 days of stratification the seeds were germinated in sand flats in the greenhouse. There were 4 replicates of 100 seeds for each treatment. Greenhouse temperatures were about 78° F. during the day and about 58° at night. Seeds that germinated were counted and removed from the flats each week for about 40 days until no more germinated (table 2). Seeds that erected a plumule above the surface of the sand were considered to have germinated.

An analysis of variance was made for the number of seeds *breaking dormancy* during stratification. There was a significant difference, at the 1-percent level, for chemical treatments, prestratification storage conditions, and their interactions.

For the basic conditions adopted for this study (fresh, cleaned seed stored 3½ months in sealed plastic bags), dry-warm storage without chemical treatment resulted in the highest germination value and the highest total germination—18 and 81.5 percent, respectively. No treatment combination involving chemicals closely approached those results.

However, after dry-cold storage, the hydrogen peroxide treatment did substantially improve germination over that for no chemical treatment (64.75 percent versus 25.50 percent). The germination value for this combination was 10. Also, after moist-warm storage, the citric acid treatment induced quicker germination than no treatment, but total germination was slightly less (54.75 percent versus 60.00 percent).

The 100-ppm. gibberellin treatments obviously were much too strong for use on black cherry seed; both treatments with

Table 2.—*Mean numbers of seed that broke dormancy and mean numbers that germinated, by periods and treatments*

Chemical treatment[1]	Pre-stratification storage condition	Number breaking dormancy,[2] by days in stratification			Number germinating,[2] by days in germination flats		
		90	104	118	7	22	40
None	Dry-warm	5.25	36.75	69.75	50.0	81.0	81.5
	Dry-cold	.50	6.50	14.50	4.25	24.5	25.5
	Moist-warm[3]	12.00	25.00	52.00	23.0	58.3	60.0
	Moist-cold	0	.25	1.25	.25	2.25	2.5
Hydrogen peroxide (3% solution for 48 hours)	Dry-warm	2.50	12.50	43.50	15.75	46.25	46.50
	Dry-cold	7.00	29.25	58.00	39.00	63.50	64.75
	Moist-warm	9.00	13.75	37.50	17.75	57.25	59.75
	Moist-cold	2.00	4.25	6.75	1.25	9.0	10.50
Citric acid (1% solution for 48 hours)	Dry-warm	.50	2.50	15.25	3.50	26.50	28.00
	Dry-cold	.25	2.25	10.00	3.25	25.25	25.75
	Moist-warm	12.75	23.00	36.50	23.50	54.00	54.75
	Moist-cold	0	.25	1.00	.25	4.75	5.00
Gibberellin (100 ppm soution for 24 hours on 90th day)	Dry-warm	.75	.75	.75	0	0	0
	Dry-cold	.50	.75	1.00	0	0	0
	Moist-warm	3.50	5.25	6.00	0	0	0
	Moist-cold	0	0	0	0	0	0

[1] No seeds treated with gibberellin before stratification broke dormancy.

[2] Mean of four replicates of 100 seeds each.

[3] Only three replicates for this treatment.

this solution completely inhibitied germination. However, results in the third study, noted later, indicate that much weaker gibberellin solutions may speed up germinations, although not without reducing total germination somewhat.

Study III

In contrast to the preceding studies in which fresh seed was used, the third study dealt with seed stored for 15 months before stratification. The seed was part of the 1963 collection used in the second study. Hence, for certain treatments that otherwise were identical in the two studies, the effect of 15 months' storage on rate and total amount of germination could be ascertained by direct comparison.

The cleaned, surface-dry seed was placed in storage in early October 1963 and was removed for chemical treatments and stratification in January 1965. The experimental variables were:

Three storage regimes.—Dry-cold 15 months, dry-warm 15 months, and dry-cold 14 months followed by dry-warm 1 month.

Four stratification periods.—90, 105, 120, and 140 days.

Four chemical treatments (applied just before stratification).—(1) no treatment; (2) soaked 48 hours in 3-percent solution of hydrogen peroxide; (3) soaked 24 hours in 1-percent solution of citric acid; and (4) soaked 8 hours in a 10-ppm. solution of gibberellins.

All combinations of storage regime and stratification period were studied, but the three chemicals were applied only to seeds destined for 90 days' stratification. Hence there were 21 treatment combinations, as shown in table 3. Two replicates of 100 seeds each were assigned to each treatment.

The cold storage and stratification treatments were carried out in a refrigerator at 34°—38° F. The stratification medium was moist peat. Each replicate was stratified in a separate polyethylene bag. Seeds were removed from stratification at the end of the assigned periods and germination was determined in sand flats in a greenhouse. Seedlings were tallied and removed twice a week for 4 weeks, then once a week until no more seedlings

appeared. Ungerminated seeds were examined by cutting to determine whether they were (1) unsound (empty), or (2) sound but still dormant, or (3) originally sound but now rotted.

Analyses of variance run on both the total germination percentages (transformed) and on the germination values showed significant differences due to treatments in both sets of data.

For seed stored 15 months, dry-cold storage for the full period consistently resulted in better germination than the other storage regimes. This is in marked contrast to the results after 3½ months' storage (second study) where germination was highest after dry-warm storage, and was only 25.5 percent after dry-cold storage (table 2). In the present study, the seed stored dry-cold germinated best—74 percent—after 120 days' stratification (table 3). However, this top figure was appreciably below

Table 3.—*Total percentages and germination values of black cherry seed stored 15 months, by treatments*

Seed storage	Stratification period	Chemical treatments	Total germination, percent	Germination Value
Dry-warm	90	None	10.5	0.9
	105	"	22.5	2.5
	120	"	25.0	2.5
	140	"	17.0	1.1
Dry-cold	90	H_2O_2	0	0
	90	Citric acid	24.0	3.9
	90	Gibberellin	24.0	3.6
	90	None	63.0	30.6
	105	"	51.0	15.7
	120	"	74.0	26.3
	140	"	62.5	15.5
Dry-cold plus 30 days warm	90	H_2O_2	61.5	28.0
	90	Citric acid	70.5	42.1
	90	Gibberellin	57.0	22.2
	90	None	52.5	19.7
	105	"	53.0	8.2
	120	"	50.5	12.1
	140	"	44.5	6.2
	90	H_2O_2	9.0	.6
	90	Citric acid	36.5	11.0
	90	Gibberellin	38.5	11.2

the top figure of 81.5 percent recorded for dry-warm storage in the second study, and may reflect some slight deterioration of the seed in storage.

Results in the present study show that dry-warm storage is detrimental when seeds are stored more than 1 year. Only 25 percent germination was obtained after 120 days' stratification; 50 percent or more of the seeds still remained dormant. Some additional treatment—perhaps warm-moist stratification before cold stratification—would be required to get more of the seed to break dormancy.

None of the chemical treatments increased total germination. However, the citric acid treatment did increase the rate of germination, and the total germination for seed stored dry-cold—70.5 percent—was not significantly lower than the top figure of 74 percent for seed given no chemical treatment. The germination value for this citric acid treatment was 42.1—the highest value obtained for any treatment in the three studies. The 10-ppm. gibberellin treatment also speeded up germination but tended to reduce total germination.

More of the seeds treated with chemicals rotted in the germination flats. Rotted or unsound seed among those chemically treated averaged 24.1 percent, as compared with 13.6 percent among those not so treated.

DISCUSSION

In this section, each of the steps in handling black cherry seed—from seed collection to seed sowing—is treated separately. The discussions are based on both our own experience and relevant information in the literature.

Seed Collection

Although open-grown, orchard-type black cherry trees produce abundant seed and offer easier opportunities for collecting seed than trees in well-stocked forest stands, collectors should avoid

orchard-type trees for genetic reasons if the seed is to be used to grow trees for timber production. The progeny of forest-grown trees can be expected to be somewhat similar to the parent in form and growth-rate, but there is little basis for judging these characteristics in orchard-type trees.

Most seed collected from standing forest trees has to be done by expert tree climbers. If trees of suitable quality are being cut at the right time on timber sales, seed can easily be collected from the felled trees. The ideal time is just before the fruits are fully ripe. At this stage the fruit clusters will cling to the branches when the tree is felled; later much of the fruit will drop when the tree is felled.

During the ripening season, the fruits at any given time will vary in ripeness from tree to tree, and even on the same tree. Fruit skins may range from green to red to black. When the skins are green, a few seeds should be cut open to see if the embryo fills the seed cavity. If the cavity is not filled (by the embryo), the seed is not ripe enough to pick. The *Woody-Plant Seed Manual* (*20*) states that if the seed coats within the stones are tan to brown, somewhat green fruits can probably be collected safely. When the cherry skin turns red, the embryo is usually mature; and when the skins become black, the fruit starts dropping from the trees. When the fruits have started to fall naturally, they can be collected from standing trees by spreading cloths under the crown and having a climber shake or beat the branches. In heavy seed years, ground cloths can be spread and left under selected trees to catch the natural fall. The catch should be removed frequently—perhaps daily—to minimize losses from rodents.

Seed Cleaning

The pulp can be removed from the seed more easily if the fruit is spread out in a cool place for a few days for further ripening. The time required will vary with the degree of ripeness of the fruit when picked. Fruits with green-colored flesh seldom become red or black; usually they turn brown, then the pulp starts to dry and soon becomes almost impossible to

remove. When seed is picked in this condition, it should be stratified immediately in peat outdoors over winter with the pulp on. Good germination (86 percent) was obtained with seed handled in this manner (table 1, treatment 7).

In studies at the Eastern Tree Seed Laboratory involving different techniques for removing the pulp from black cherry seeds, Leroy Jones found that soaking the fruits in running tap water for 10 days was detrimental: no seeds germinated. He also found that germination was decreased when water was added to a mass of freshly picked fruit and the pulp was allowed to ferment (*11*).

Large quantities of seed can be cleaned by running the fruits in water through a macerator or hammer mill and floating or skimming off the pulp (*20*). Seeds at the Warren Laboratory have been cleaned by mashing the fruits in a potato ricer while in a small stream or under a stream of tap water. The cherry skins, being lighter than the seeds, will rise and can be floated off with the help of the water current.

Is Pulp Removal Necessary?

When the pulp is removed from ripe cherry seeds, germination is increased. In seed studies at the Saratoga, New York, nursery, Heit (*5, 6*) found that seeds without pulp germinated better than seeds with pulp. Hough (*8*) also reported that removal of the pulp increased germination; in fact, his seeds sown with pulp intact did not germinate at all.

Patton (*17*) studied several preplanting treatments of black cherry seed at the Wooster, Ohio, nursery. He found that fall-sown seed that was practically free of pulp began germinating earlier and faster than seed that had been sown with the pulp intact, or seed that was mashed free of pulp but not washed, or seed that had been soaking in water to which lye had been added. However, within about a month after the beginning of germination, differences among the test beds had largely disappeared. He concluded that it was unnecessary to treat black cherry seed in any way to get adequate germination, and that the earlier germination gained by cleaning the seed probably

does not justify the labor involved. However, we feel that early germination is desirable because a period of dry weather later in the spring might prevent germination of the tardy seeds.

Kain and McQuesten (*12*) have reported that rosaceous seeds germinate best when freed from the ripe, fleshy parts, washed clean, and dried before storage and subsequent stratification.

In our studies at the Warren Laboratory, cleaned black cherry seed that was kept moist germinated better than moist seed with the pulp left on (given the same stratification treatment). However, when dried 30 days before outdoor stratification, seeds with pulp germinated about as well, or better, than cleaned seed (table 1).

In an exploratory study in 1963, apart from the three studies previously discussed, Cleaned seed and seed with pulp was stored dry in open containers at room temperatures for 10 months, then stratified in sand for 9 months. Germination after this treatment was somewhat better for the seed with pulp (72 percent versus 57 percent).

Hartman and Kester (*4*) report that "the fruit or seed coverings of stone fruits, or the juices from them, contain substances that rather strongly inhibit germination. In nature the decomposition of the seed coverings takes place by various agencies of the environment". Consequently, to obtain good germination of seed that has not had the pulp removed, the seed must be handled by methods that will bring about decomposition of the inhibitory pulp and its juices.

Hartman and Kester suggest a period of warm stratification (68° to 86° F.) before the usual cold stratification. The warmer temperatures favor the micro-organisms that break down the pulpy coverings, whereas the temperatures of 32° to 50° F. needed for after-ripening inhibit micro-organism activity. A constant intermediate temperature near 50° F. may sometimes be effective, because this is within the lower temperature range for micro-organism activity and also is within the upper range for after-ripening. However, the period of time needed would usually be somewhat greater than when warm and cold treatments are used consecutively. In any event, the seeds should never be

allowed to dry out if maximum germination is desired during the first year after seed collection.

Seed Storage

Storage conditions are an important consideration for black cherry seed that is not to be fall-sown immediately after collection. The main essentials are access to oxygen to promote after-ripening, prevention of heating, prevention of excessive drying, and, for storage periods of 1 year or more, temperature ranges of 33° to 40° F.

Polyethylene bags are useful both for storing and for stratifying seed because this material permits diffusion of oxygen and carbon dioxide between the inside and outside air with only minimal loss of moisture. Polyethylene is light, tough, flexible even when cold, and transparent—seeds in stratification, for instance, can be observed for sprouting without opening the bags. Small to medium-size bags are preferable to larger ones, not only because of easier handling, but, more important, because aeration is better and the likelihood of heating is less when the volume of seed is relatively small. Although we have not determined an optimum size of bag for storing black cherry seed, tests with loblolly pine and slash pine seed provide some guidelines: seed of these species germinated better after storage in 5- and 10-pound bags than after storage in 25-pound bags (*15*).

Black cherry seed should not be permitted to dry out during the period between cleaning and stratification. If the seed is to be stored briefly before placing it in stratification, only the surface moisture should be removed to prevent molding. Shumilina (*19*) found that drying the seeds of sour cherry (*Prunus cerasus* L.) for only 10 days before stratification reduced germination. With each increase in length of drying period there was a further reduction in germination. Shumilina referred to several other Russian reports on sour cherry that, in general, are in accord with his observations of the adverse effects of drying the seed. One of these reports recommended that cherry seeds be sown or stratified only in a fresh condition immediately after picking. Another said that cherry seeds could be dried before sowing or

stratification, but only for a short period. Another said that cherry seeds will not germinate the next spring if stratification is delayed 1½ months.

In our first study at the Warren Laboratory, germination was reduced when cleaned seed was permitted to dry 15 or 30 days at summer temperatures under a roof. Germination for fresh seed stratified in peat immediately after cleaning was 86 percent; when 15 or 30 days' drying preceded stratification, germination was 74 and 31 percent, respectively (table 1). In other experiments, seeds dried 2 months and 3 months at warm temperatures and then sown in field beds germinated very poorly the following spring. Most of these seeds laid over and germinated the second spring.

We have not yet determined the best combination of temperature and moisture content of seed for storage periods of 1 year or more. A long-term storage study started in 1965 is expected eventually to provide a basis for prescribing storage conditions.

We know that fresh, cleaned black cherry seed, after having been spread out about 4 hours at 72° to 78° F. to dry off the surface moisture, will have a moisture content of 20 to 30 percent (based on dry weight). And we know that the moisture content of such seed will decrease in storage unless the seed is sealed in air-tight containers. In one of our experiments, the seed moisture content dropped to 11 percent after 2½ months' storage at room temperature in a large polyethylene bag that had been closed by twisting the top and fastening tightly with a rubber band. Seed from the same batch stored at the same temperature in a screw-capped but not completely sealed glass container had a moisture content of 14 percent after 1 year. In another experiment, surface-dried seed stored in a refrigerator at 33° to 38° F. still retained 30 percent moisture after 6 months in a sealed glass container, but in a paper box the moisture had dropped to 14.5 percent.

First-year results in the long-term storage study point to a seed moisture of 12 to 15 percent and a temperature of 33° to 41° F. as effective conditions for maintaining seed viability.

Pre-Stratification Treatments

Several chemicals have been used successfuly to overcome seed dormancy and to stimulate seed germination of various conifer and hardwood tree seeds (*1, 3, 10, 14 16, 17, 18*). In studies on black cherry seed at the Eastern Tree Seed Laboratory, Leroy Jones (*11*) found that a 48-hour soak in a 0.1 percent citric acid solution preceding 120 days' stratification increased germination from 57 percent for untreated seed up to 89 percent for treated seed. He reported that a 30-minute soak in sulfuric acid before stratification reduced germination. Hood and LaVoie used the sulfuric acid treatment followed by 120 days of moist-cold stratification at 39° to 41° F. and obtained only 8 percent germination, as compared to 52 percent germination by seeds that were not acid-treated.[1]

However, E. I. Roe treated black cherry seed with sulfuric acid and obtained 76 percent germination versus 64 percent by untreated controls. In his study Roe found that sulfuric acid was harmful to seed that had passed through a captive robin; germination was reduced from 87 percent to 59 percent. He believed these seeds were damaged by the acid because the seed coats had been reduced in thickness or otherwise altered by passage through the bird's digestive tract. As further evidence of seed-coat changes, Roe stated that, after 120 days of cold stratification, the robin-passed seed germinated much better and more rapidly than control seeds.[2] This subject is discussed also in an article by Krefting and Roe (*14*). They found that many kinds of seed, after passage through the digestive tracts of animals or birds, after-ripen in less time and germinate earlier in seedbeds than seeds not subjected to such digestive action.

Several chemicals were tried by Defler[3] to hasten germination. He found that concentrated sulfuric acid was detrimental to germination and that acid-treated seeds were more susceptible to attack by molds. He concluded that stratification in peat moss below frost line for 90 days at about 36° F. induced better germination than any chemical treatment.

[1] Hood, G. A. and K. LaVoie. Personal communication, 1963.
[2] Roe, E. I. Personal communication, 1962.
[3] Defler, Samuel E. BLACK CHERRY: CHARACTERISTICS, GERMINATION, GROWTH, AND YIELD. Thesis, N. Y. State Col. Forestry. 1937.

The usual purpose of acid scarification is to modify hard or impermeable seed coverings (*4*). Black cherry seed coats are not impermeable because the micropyle is open, thus permitting air and moisture to reach the embryo during after-ripening and germination. However, the seed coats are relatively hard, and their physical resistance to expansion of the embryo may vary considerably with method of seed storage. Defler[3] observed that seeds stored under moist conditions split readily, whereas seeds stored air-dry exhibited much resistance to pressure before cracking.

The chemical seed treatments tried at the Warren Laboratory, and reported in this publication, did not stimulate seed germination enough to warrant their use. Seed that was properly handled and stored germinated better without treatment than with any of the chemical treatments.

Seed Stratification

The period of stratification needed to prepare black cherry seed for germination varies with the age of the seed and its environment from the time of collection. Fresh seed will need less stratification to break dormancy than seed that has been stored a year or longer. Cleaned seed will need less stratification than seed with pulp.

Dale E. Kester (*13*) discussed the environmental influences of water, aeration, and temperature on stratification of Mahaleb and Mazzard cherry seed. After-ripening does not take place in a dry seed. After-ripening requires air—presumably oxygen—and cool temperatures: from 32° F. or slightly below to around 55° or 60° F. It ceases and, in some cases is reversed, at higher temperatures. Stone fruits properly stratified and then sown when unseasonably high temperatures prevail may fail to germinate the first year; instead, they may lay over and germinate the following year. Kester says that length of time required for stratification is closely related to temperature. The shortest time is required at optimum temperatures. As the temperature deviates from optimum, the stratification requirements become longer and longer.

The proper soil environment for stratification of seeds was studied by Shumilina (*19*). He used sand, humus, and peat as stratification media for sour cherry seed (*Prunus cerasus* L.) and found that peat provided the most favorable combination of moisture and aeration. He determined the field capacity and maximum capillary capacity of these media for water. The field capacity was 24 percent for forest sand, 169 percent for humus, and 322 percent for peat. Sixty percent of field capacity was considered the optimum moisture condition. The distribution of moisture was more nearly uniform in peat. Shumilina found that aeration in peat was twice as high as in sand. He states that Krocker and Belokhonov also concluded that peat was the best stratification medium, and further, that Krocker had shown the excessive acidity of peat to have no adverse effect on the seeds. In his study with sour cherry seeds, Shumilina obtained 85 percent germination with peat stratification, 64 percent with humus, and 65 percent with sand.

Shumilina found that fresh cherry seeds could be prepared for spring sowing by stratification in trenches immediately after harvest. Thus the seeds would have 4 to 5 months' time to be prepared for germination before freezing of the trench. Dried seeds require more time and therefore should be stratified in "warm trenches"—trenches covered with enough straw and snow to protect the seed from freezing during the winter.

Defler[3] reported that black cherry seed stratified in peat moss at 40° F. from time of cleaning until spring sowing produced about four times as much germination as cleaned seed sown immediately in the fall. Height growth after one season also was greater for the spring-sown seed.

In our black cherry seed studies at the Warren Laboratory, we found that uncleaned seed stratified immediately after collection needed a warm period of 3 to 4 months to decompose the pulp and bring about certain essential internal changes before beginning the 120-day cold stratification. Also, cleaned seed that was to be sown the next spring after collection, needed a period of warm storage before cold stratification. As shown in our second study, seed held in cold storage before stratification ger-

minated poorly (table 2). Yet, when seed was stored dry-cold 15 months and then stratified 120 days, 74 percent germinated (table 3). Obviously the internal changes that prepare the seed for germination proceed much more slowly at 34° to 38° than at room temperature.

A method of stratification that has given satisfactory results for us is refrigerator stratification in peat in small polyethylene bags. About four times as much peat as seed, by volume, was used in our experiments. The peat was left in water overnight; then the free water was drained off and the seed was mixed with the wet peat. Outdoor stratification in peat or sand in shallow wooden frames with screen tops and bottoms, as described under the first study, also gave good results. Peat was somewhat the better of the two media in our outdoor experiments (table 1).

Seed Germination

Black cherry seed has a hard seed coat. Water can penetrate the seed coat through a single micropylar channel that starts at the point of attachment of the stone to the fruit stalk and opens near the radicle of the embryo (*19*). Hough states that germination does not depend on the partial decomposition of the bony seed coat by soil organisms, or by passing through birds, or upon splitting of the seed coat by frost. Before germination will take place, the seed requires a period of after-ripening that, under natural conditions, occurs over winter in the forest floor (9).

At the time of germination in the spring, the embryo swells and splits the shell of the stone into two halves. The radicle emerges and may grow an inch or two in length while temperatures are still below 40° F. Plumule growth does not usually occur at these temperatures.

In our second study, seeds that had been stored moist-warm began breaking dormancy after about 90 days in stratification, and after 120 days many of the radicles were ½ inch or more long. In the first study, seeds stratified in peat in the refrigerator similarly broke dormancy after about 120 days and began radicle growth. Seeds with a protruding radicle of ½ inch or more are

hard to handle for sowing because the radicles are easily broken. A broken radicle often results in failure of the little plant to survive, even though a plumule may appear.

Some surplus seed from the first study was left in the refrigerator for about a year after it began to break dormancy. The radicles continued to grow slowly during this time, attaining lengths of 1.5 inches or more, but plumule growth was evident in only a few seeds and then did not exceed ¼ inch. When these held-over seeds were sown in sand flats in a cool greenhouse (44° to 60° F.) the plumules began to grow and developed in a normal manner. Some seedlings were 10 inches tall in May and up to 20 inches by mid-June.

Under natural conditions cherry seeds drop to the forest floor in late summer and are covered later by the annual leaf fall. Germination begins in late March, and occasionally earlier, in northwest Pennsylvania. On one occasion we found seeds sprouting under a 34-inch snow cover on March 8. Mean daily temperature for the preceding February had been 13° F., and —30° F. was recorded on February 27. However, the forest floor under the snow was not frozen. The radicle of germinating black cherry seeds easily penetrates the duff and soil of the forest floor, and numerous seedlings become established in the vicinity of seed trees after good seed years.

Fall Sowing

Fresh black cherry seed may be fall-sown where there is no rodent problem. This eliminates the storage and stratification handling that is necessary for spring sowing. Seed that has not been cleaned of pulp should be sown as soon as possible after collection to assure a period in moist soil at moderate temperatures long enough for the pulp to completely decompose. The winter period in the soil will then satisfy the chilling requirement. Heit (7) found that if fall sowing is delayed beyond October 15, reduced germination will result. Seed with pulp that has been stored dry for a year or more probably should be sown or stratified by late summer because decomposition of the dried pulp will take longer than with fresh fruit.

In studies at the Saratoga nursery, Heit (*6*) found that black cherry seed sown by September 20 gave considerably better germination than that sown October 23. Cleaned seed germinated better than seed with pulp. Seed with pulp, sown October 23, did not germinate the following spring in beds that were not mulched to prevent freezing. Mulching increased germination in both early and late sowing.

RECOMMENDATIONS

Fresh seed that is to be sown the following spring should have the pulp removed, be surface-dried,[4] and then be stored in sealed polyethylene bags at room temperature until stratified. The seed should be stratified at 32° to 38° F. for 120 days before the planned sowing date. Peat is recommended as the stratification medium.

If removal of the pulp is not feasible, the seed should be stratified in moist peat or sand at 68° to 78° F. during September, October, and November, and then it should be stratified cold for 120 days before spring sowing.

If seed with pulp is to be fall-sown, the sowing should be done no later than October 15, and the beds should be mulched to prevent freezing.

When seed is to be held in storage for a year or more, it should first be cleaned of pulp and surface-dried,[4] then placed in small polyethylene bags sealed to prevent excessive drying, and stored at 32° to 38° F.

■

[4] Time required for surface drying varies; it might require only a few hours in a heated room, or it might take a day or two under less favorable drying conditions.

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Planting
PAPER BIRCH
in Old Fields in Maine

by John C. Bjorkbom

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Planting PAPER BIRCH in Old Fields in Maine

A PROBLEM IN PLANTING HARDWOODS

PLANTING paper birch *(Betula papyrifera* Marsh.) on abandoned farmland has been suggested as a means of improving birch wood supplies for the turnery industry in Maine. However, in the past, planting hardwoods in old fields has not been very successful.

One of the reasons for this lack of success is the heavy sod cover that generally is present. The grasses that make up the sod absorb moisture more rapidly than tree seedlings, and the grasses also can endure a lower wilting point *(1)*. Thus when soil moisture supplies are low, the grasses can lie dormant, but the tree seedlings die. However, if the sod is removed, planted seedlings have time to establish their own roots so that they can compete successfully with the lower vegetation *(2)*. In addition to competing with seedlings for moisture and nutrients, sod roots have been found to act as a barrier to seedling root extension *(5)*.

In 1959, we began a study in western Maine to evaluate different treatments for reducing sod competition so that we could determine the practicality of planting paper birch in old fields.

Five birch-using companies, listed in table 1, cooperated in the study by contributing land, labor, and materials. The Soil Conservation Districts in Franklin and York counties contributed the use of tree-planting machines and a tractor.

PLANTING SITES AND PROCEDURES

Seven plantations were established in fields typical of those found in western Maine. These fields had been pastured or mowed for hay in the past. Some had been abandoned for several years; others were in active use until taken over for this study (table 1).

The planting sites were approximately ½ acre in size. In general, the soils were well-drained sandy loams. Elevations ranged from 400 feet to 1,000 feet. The aspect was either level or southerly except on one site where the slope was to the north. All slopes were gentle.

Four treatments, each representing a different combination of site preparation, planting method, and planting position, were studied. These treatments were as follows:

- Plowed double furrow, with second slice turned over into first furrow; trees hand-planted on the second slice.
- Plowed single furrow; trees hand-planted in the bottom of the furrow.
- Scalps, 16 inches wide, done with attachments to a Lowther planting machine; trees machine-planted in center of scalped strip. (In practice, the scalps were not always full width because the blades fouled with debris.)
- No sod removal; trees machine-planted directly in the sod.

The plan called for 150 trees to be planted per treatment combination at each site, or a total of 1,050 trees per combination for the seven sites. However, because of shortages and because some gray birch was intermixed, the numbers of paper birch actually planted ran a little lower. The totals per combination ranged from 985 trees to 1,006 trees.

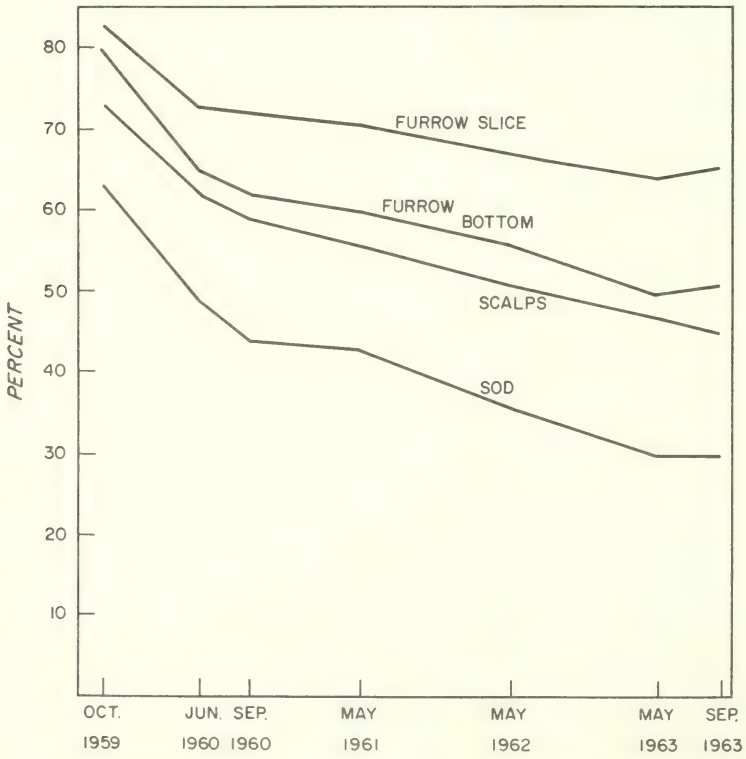
Table 1.—*Description and ownership of the plantation sites*

Plantation	Prior land use	Sod depth	Aspect	Elevation	Soil	Drainage	Cooperator
		Inches		*Feet*			
1	Mowed and pastured, abandoned 5 years	2-3	Level	900	Sandy loam	Well-drained	Diamond-International Corp.
2	Last cut for hay 14 years before planting	3	Southeast	900	Sandy loam	Well-drained	Diamond-International Corp.
3	Last cut for hay 4 years before planting	2-3	Southwest	1,000	Sandy loam	Well-drained	Maine Dowel Corp.
4	Active pasture with fertility maintained	3-4	Southwest	600	Sandy loam	Well-drained	Maine Dowel Corp.
5	Active pasture until planting established	2-3	Level	400	Sandy loam	Well-drained	Forster Manufacturing Co.
6	Old pasture-inactive at least 10 years	3	Northeast	900	Sandy loam	Well-drained	C. B. Cummings & Sons
7	Mowed until planting was established	3-4	Level	600	Loam	Moderately well-drained	Saunders Brothers

Planting was done, at approximately 6-foot spacing, during the last week in April and the first week in May. The planting stock (2-0 seedlings), grown from seed of an unknown source, was of only fair quality. Most of the finer roots had been lost when the seedlings were lifted from the nursery beds. Seedling heights ranged from as little as 1 inch to as much as 32 inches, and averaged about 9 inches.

The first seedling measurements were taken after planting in the spring of 1959. Subsequent measurements and observations were timed to coincide with the start of growth and with the time just before leaf fall. Only the spring measurements were made in 1961 and 1962. The final measurement was made in September 1963.

Figure 1.—Trends in seedling survival by site-preparation method, October 1959-September 1963.



RESULTS

Survival and Mortality

After five growing seasons, survival varied considerably within treatments among the seven plantations. But, variations notwithstanding, a definite pattern among the four treatments can be seen. Generally, survival was best on the furrow slice, better in furrow bottoms than in scalps, and always poorest in the sod.

The percent of survival by treatment and plantation is given in Table 2, and the trends in survival for all plantations combined are shown in figure 1.

Of the 3,954 seedlings planted in these seven plantations, some 2,000 died during the five growing seasons. About three-fourths of this mortality occurred in the first year after planting. The mortality was consistently heaviest among seedlings machine-planted in the sod and generally was least among seedlings planted on the furrow slice. Mortalities in furrow bottoms and in scalps, roughly equal, were in a median position. Table 3 shows the average total mortality by treatment and cause for all plantations combined.

Of the total mortality, about 12 percent was ascribed to planting failure—seedlings dying within 1 month after planting.

Table 2.—*Percent of seedling survival, by treatment and plantation, September 1963*

Plantation	Treatment			
	Furrow slice	Furrow bottom	Scalps	Sod
	Percent	*Percent*	*Percent*	*Percent*
1	90	73	65	46
2	86	71	54	49
3	66	55	64	32
4	50	8	20	3
5	48	58	47	38
6	64	75	50	39
7	46	14	20	0
Average	65	51	45	30

Planting failure was greatest in the sod but was almost equaled by that on the furrow slice. This relatively high mortality associated with the furrow slice probably occurred because the loosened soil with its turned-under litter was especially subject to drying out.

Another 12 percent of the mortality was caused by mice. Stems were completely girdled or, in some cases, cut through. Most of this occurred during the first year after planting. Included with this mortality was a nominal amount of mortality due to rabbits and/or hares. In general, mortality caused by mice was greatest in those treatments that provided maximum cover so that mice could move with safety. Such cover was provided best by the furrow bottoms with overhanging vegetation. In one old field in which the soil fertility had been maintained, a luxuriant growth of grasses developed and provided almost perfect cover. In this particular field, mice accounted for about three-fourths of the total mortality.

Most of the mortality—76 percent—was due to other causes or to multiple causes in which the identity of the primary cause was uncertain. Included here are contributing factors such as poor root system, poor planting, dry soils, wet soils, competition from other tree seedlings, smothering by dense grass, frost heaving, damage from vehicles, and damage from deer walking in the furrows.

Table 3.—*Average mortality for all plantations by treatment and by cause, May 1959 to September 1963*

Treatment	Total mortality	Mortality by cause			
		Planting failure	Mice	Other	Total
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Furrow slice	35	14	8	78	100
Furrow bottom	49	9	21	70	100
Scalps	55	10	12	78	100
Sod	70	15	8	77	100
Average	52	12	12	76	100

Some seedlings simply were missing, or were not found and were presumed to be dead. Unfortunately, in most cases, the primary cause of death could not be ascertained.

Height Growth

In general, average height after five growing seasons was greatest on the furrow slice and was progressively less in the furrow bottoms, scalps, and sod. Average height varied among plantations as well as among treatments (table 4). The heights reached in plantations 3 and 4 were substantially greater, treatment for treatment, than those in any of the other plantations.

Table 4.—*Average height of seedlings, by treatment and plantation, September 1963*

Plantation	Treatment			
	Furrow slice	Furrow bottom	Scalps	Sod
	Inches	*Inches*	*Inches*	*Inches*
1	41.2	28.0	22.7	23.6
2	41.5	32.1	30.1	25.7
3	61.2	42.5	45.4	35.0
4	58.8	45.5	40.5	60.5
5	38.8	34.1	27.4	30.0
6	32.5	32.1	27.2	24.6
7	33.7	24.9	17.5	.0
Average	43.9	33.2	30.1	27.6

We don't know why this is so. However, the soils in these two plantations appeared to be deeper and better drained and, perhaps, had higher available nutrient levels. Plantation 4 was in a field in which fertilizer had been applied by the previous user.

Mean seedling heights at the time of planting had varied slightly by treatments, as follows: furrow slice—9.4 inches, furrow bottom—9.4 inches, scalp—8.7 inches, and sod—8.2 inches. Thus, the respective amounts of 5-year height growth, derived from these figures and total heights (bottom line of

table 4) were 34.5 inches, 23.8 inches, 21.4 inches, and 19.4 inches. The differences in growth among furrow bottom, scalp, and sod planting were relatively small, whereas growth on the furrow slice was 10.7 inches to 15.1 inches greater than growth on the other treatments.

ANIMAL DAMAGE AND PROTECTIVE MEASURES

Practically all of the seedlings were damaged in one way or another during the 5-year observation period. The damage was mainly, but not entirely, caused by animals. Deer and mice were responsible for one-half of the total incidence of damage, and about one-third of the damage was due to unknown causes. The rest of the damage came from insects, rabbits, hares, frost heaving, and snow.

Deer browsing was most common on seedlings planted on the furrow slices and in the furrow bottoms. Presumably the greater height of these seedlings made them easier to see and to browse. Also, the more rapid growth of these seedlings perhaps made them more succulent and palatable.

Damage from mice was also greatest on the seedlings planted on the furrow slices and in the furrow bottoms—situations that appeared to provide the mice with maximum protection from predators.

Because animals caused much damage to the seedlings, we conducted a study on animal repellents that protect seedlings against deer, rabbits, and hares. And we also tried direct measures to reduce mouse populations.

The study plan called for trials of four animal repellents: Arasan, Diamond L, Z.I.P., and lime paste. These were applied shortly after planting and again in the fall, and applications were repeated in the spring and fall in subsequent years. Besides providing a comparison of the efficacy of the different preparations, we hoped that at least some of the repellents would reduce deer and mouse damage sufficiently to permit the effects of the planting treatments to be fully expressed in seedling growth.

However, all the repellents as used in these trials were ineffective. The long intervals between applications, plus the relatively high animal pressure on the plantation areas, mainly accounted for the poor results.

Frequency of application is important for two reasons. The first relates to the new growth of the planted seedlings. An early spring application of a taste repellent does not protect the new growth as it develops. Therefore, to be most effective, the repellent would have to be applied frequently enough to keep the new growth covered. Second, repellents undergo a weathering action after application, and consequently must be renewed as the occasion demands. The addition of so-called "stickers" to repellents before application slows the weathering action but is not completely effective.

The evaluation of animal pressure is more elusive. Pressure depends not only on the animal population at the moment but also on the amount and availability of preferred foods and other natural foods, on the abundance of predators and on their hunting success, and on other animals competing for the same food and shelter. However, we do know that the pressure—both from deer and from mice—was high enough in our plantations to cause severe damage.

In September 1960, a mouse control program in which poisoned baits were used was initiated by the Division of Wildlife Services of the U. S. Department of the Interior. This program was designed to minimize seedling damage and mortality by reducing the mouse population. The same program was followed again in the fall of 1961. Censuses made before and after treatment indicated that the procedure was extremely effective. No mortality of other wildlife was observed.

But the real effect of the control program is hard to assess. Seedling mortality and damage already had begun to decrease before the first treatment. The mouse populations on the plantations were reported to be very low at the time of the second treatment. And there is no way of knowing whether the reduction in seedling mortality and damage was due to the control program, to a natural decline in mouse population, to some other factor,

or to a combination of several factors working together. Yet in spite of the inconclusive results, this type of control shows some promise.

DISCUSSION

The results of this study show that survival and growth of paper birch seedlings planted in old-field sites are far better when the sod cover is removed than when it is left intact. The method of removal is of little importance except as associated with width of de-sodded strip, or with some other change in the micro-environment. Among our treatments, the loosened soil of the second slice of a double furrow, although relatively unfavorable for initial survival, definitely produced the best growth in seedlings that did survive the first critical weeks after planting.

There are a number of factors other than planting-site preparation that might have a pronounced effect on seedling survival and growth. Among these are the site itself, the quality of the planting stock, the quality of the planting job, the amount of animal damage, and the aftercare of the planted seedlings. However, this study was set up to measure only the effects of site preparation and, secondarily, to measure the effects of certain animal repellents. Other factors were not measured or analyzed.

The sites in this study were selected to be representative of old fields in western Maine, and they were considered favorable for growing paper birch. Except perhaps for those sites that tended to be dry, it is doubtful that the planting site itself had a great influence on survival. Warmer-than-average temperatures and considerably less-than-average precipitation in the month immediately after planting *(6)* may have caused an above-average mortality on the naturally dryer sites.

However, site did seem to influence growth. The better height growth reported for two plantations is believed to be due more to site than to any other factor. Both plantations were situated on upper slopes where good drainage might to expected. Both sites supported a dense growth of grasses, indicating higher-than-average nutrient levels; in fact, one of the plantations was a field

in which soil fertility had been artificially maintained. None of the other plantations quite met this description. The inference is, of course, that the physical and chemical characteristics of the soils were more favorable for paper birch on these two sites.

The quality of the planting stock may have contributed to low survival and to reduced or delayed growth. At the time of planting, we observed that the root systems of many of the seedlings had lost most of the fine rootlets. Also, some seedlings were too small to meet accepted standards for field planting stock. Planting only those seedlings that are at least 6 inches tall and that have well-branched, fibrous root systems should appreciably increase both survival and growth.

The planting method and the care with which it is carried out might also affect survival and growth. The center-hole method, using a mattock, was specified for the hand planting, but different crews of varying experience worked at the different places. Some poor planting, with roots bent and folded, doubtless was done. The machine planting compressed the roots in one plane, and the quality of this planting probably varied with respect to depth and positioning of the trees. Root distortion and compression in one plane sometimes adversely affect survival and growth *(3)*, but the manifestation of these adverse effects may be delayed *(4)*.

Despite the difficulties encountered and the less-than-complete success in the study plantations, there are indications that successful plantings of paper birch can be made. The isolated examples of high survival and good growth provide some basis for this belief. However, certain conditions must be met. Among these conditions are deep, moist, well-drained, reasonably fertile soils; good planting stock; removal of sod cover within a space of 1.5 feet to 2 feet around the trees; careful planting; and protection from animal damage. If these conditions are met, the chances for success should be reasonably good.

If, in addition to the above conditions, after-care were provided to control the grass and the other competition around the trees, the chances for a high degree of success should be much greater. Although no after-care was provided in our study, we did observe the deleterious effects of the vegetation that developed after

planting was done. And there is considerable experience indicating that cultivation or other weed-control measures are highly beneficial — sometimes essential — in establishing hardwoods on grassy sites. So we can confidently assume that the performance of our paper birch would have been much better if the herbaceous competition had been controlled during the first 2 or 3 years.

Such control would, of course, add to establishment costs, but it might well be the key to achieving maximum success in paper birch plantings on grassy old fields in New England.

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Growth & development of older

PLANTATIONS

in northwestern Pennsylvania

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Growth & development of older PLANTATIONS in northwestern Pennsylvania

A New Look at Old Plantations

BY RE-EXAMINING some of the oldest plantations in northwestern Pennsylvania, we have gained new insights into the survival and growth of these planted trees. And we have changed some of our ideas about which species should be favored for planting in this area.

Most evaluations of the species used in plantations are based on survival and growth at an early age. Formal measurements commonly are discontinued after 5 to 10 years; and later evaluations, if any, are based on only general observations.

But the volume and value of wood products that a plantation will produce cannot be estimated with any reasonable precision until height growth has shown how the site suits each species, and volume growth is well under way. The performance of a species

may change markedly between age 10 and age 50. The relative heights of two or more planted species may differ greatly between youth and middle age.

In northwestern Pennsylvania, thanks to a previous study by J. E. Hetzel,[1] we have records on enough plantations now close to 50 years old so we can get a good idea of how valuable a number of species are for reforestation, particularly on old fields. Hetzel in 1939 had located and examined more than 40 plantations in this area, most of which were then between 18 and 27 years old. Besides his published report *(Hetzel 1941)*, we have his study files, which enabled us to relocate the plantations. His records also contained information about planting each species in each plantation.

Having this excellent data, we decided to revisit and re-measure as many of these plantations as possible. Our purpose was to evaluate the species, mainly in terms of volume production, and to compare the results in a general way with those Hetzel got in 1939.

Hetzel had recorded the height, diameter, crown class and form of a sample (usually 20 or 25 trees) of each species in each plantation. Presumably the trees were randomly selected. The records are not clear as to whether the trees were selected as a group or were scattered. In some of the smaller plantations, nearly all suitable trees obviously had to be measured.

His planting information included date, age of stock, spacing, and use of land before planting. Site data—such as elevation, frost danger, soil texture, drainage, pH, humus, and litter—were recorded. He also described the condition of each plantation and noted the presence of insects and damage due to other causes.

All but 7 of Hetzel's 41 plantations were suitable for re-measurement. We also measured three other plantings for which age records were available, making a total of 37 plantations for our study.

Although Hetzel examined only 41 separate plantations, his plantation numbers went up to 72 because he assigned a number to each species that he measured in the mixed plantings. Thus, for

[1] Then Junior Forester with the Allegheny Forest Experiment Station, which was later combined with the Northeastern Forest Experiment Station.

example, his numbers 3 and 4 refer to a single mixed planting of two species—red pine and scotch pine. Not every species was numbered in every mixture; the unnumbered species were the near or total failures. To facilitate cross reference, we have retained Hetzel's numbers in our study.

The 37 plantations ranged in age from 36 to 64 years from seed, and averaged 45 years. All but 3 of them were between ages 39 and 54.

Methods

The plantations were scattered through northwestern Pennsylvania from Erie County to Potter County and south to Venango, Armstrong, and Jefferson Counties. All were on private land or on the grounds of a state institution.

We established one temporary plot in each plantation. In larger plantations, we selected a location that had uniform site and stand conditions, particularly with regard to residual or volunteer hardwoods. This no doubt resulted in an upward bias of the stand stocking figures, but we wanted a measure of the productive capacity of a species or mixture on each site, not a sample of the average condition. We always excluded the outer two rows. Our original plan was to take plots of about 1/5 acre, but several plantations were not large enough for a plot of that size. However, all but six plots were 1/10 acre or larger. All mixed plantations were single-tree mixtures or some type of row mixture; hence only one plot was required to sample the two or more species that were involved.

On each plot, we measured diameter (breast high) to the nearest 0.1 inch on all living planted trees, and on all living volunteers that were 4.6 inches d.b.h. or larger. All basal area figures were derived from these same trees.

Crown class and form of each tree were recorded. Standard crown classes, as defined by the Society of American Foresters *(1944),* were used. Form was defined as follows:

1. Entire stem straight enough for present or potential sawlogs; no forks.

2. Straight, as above, for the butt 16-foot log.
3. Not as above, but suitable for pulpwood—at least two consecutive 4-foot bolts. (May include sawlogs or potential sawlogs above a butt section.)
4. Not suitable for pulpwood because of forks or crooks.

About 20 trees of each species in each plantation sample plot were selected for measuring merchantable and total height. These were used for computing site index and volume.

Height and diameter of all stumps judged to have supported trees 4.6 inches d.b.h. or larger were measured. We used these measurements to estimate the diameter and volume of trees that had been removed in thinnings.

In our observations and records for each plantation we included aspect, slope, crown density, condition of the plantation, evidence of pests, area of ground covered by herbs, shrubs, or tree seedlings, and soil information. Soil data included pH, type of humus, and depth of litter, F- and H-layers at two spots, and soil type. Soil types were identified by scientists from the U.S. Soil Conservation Service.

Site-index values were obtained from applicable 50 year-site-index curves for the various species. Since most of the plantations were close to age 50, the estimates should be very good.

We computed volumes from the most appropriate volume tables available. Cubic volumes for most of the exotic species were computed as in the Lake States Composite Table *(Gevorkiantz and Olsen 1955),* with appropriate corrections for bark volume and form quotient. Board-foot volumes of exotic species were obtained from Bickford's form-class volume tables for northern conifers *(1951).* Cubic-foot volumes are net volume in all trees 4.6 inches d.b.h. and up, inside bark, to a 4.0-inch top. Board-foot volumes indicate gross volume in merchantable logs in softwood trees 9.6 inches d.b.h. and up, and in hardwoods 11.6 inches and up. This was virtually the same as net volume because very little cull was involved.

Results

To our surprise we found—in this day of road-building, utility-line clearing, strip-mining, and suburban sprawl—that not a single plantation had been destroyed by land-clearing in the 21 or 22 years since Hetzel visited them.

Less unexpected was that about two-thirds of the plantations had never been thinned. Only 13 of the 37 plantations had been thinned in the 5-inch or larger diameter classes, and in 7 of the 13 thinned ones less than 10 percent of the yield had been cut.

BASIC DESCRIPTIVE DATA

Each plantation, identified by Hetzel's numbers and located by county, is described as to soil characteristics and planted species in table 1. Mean annual increment in cubic feet and in board feet also is shown as totals for all the species in each plantation. The abbreviations used in table 1 are spelled out below:

Soil Drainage Class

W =well-drained
MW=moderately well-drained
SE =somewhat excessively drained
SP =somewhat poorly drained
P =poorly drained

Soil Depth

D =deep
MD=moderately deep
MS =moderately shallow
S =shallow
VS =very shallow
VD =very deep

Species

EL =European larch
JL =Japanese larch
WP=eastern white pine
JP =jack pine
PP =pitch pine
RP =red pine
SP =Scotch pine
JBP=Japanese black pine
NS =Norway spruce
SM =sugar maple
YP =yellow-poplar
V =volunteers

Table 1.—Descriptive data and mean annual increments, by plantations

Plantation number	County	Soil type	Soil drainage	Soil depth	Species	Mean annual increment	Mean annual increment
						Cubic feet	*Board feet*
3-4	Venango	Hanover silt loam	W	D	RP, SP	74	95
5	Clarion	Sciotoville silt loam	MW	D	WP, V	69	221
6	Venango	Lordstown silt loam	W	S	SP	57	6
9	Jefferson	Brinkerton silt loam	P	D	JL, V	68	101
12-13	Venango	Lordstown silt loam	W	MS	RP, WP	87	92
14	Venango	Shelmadine silt loam	P	D	PP, WP	36	35
15	Venango	Titusville silt loam	MW	D	JBP	67	45
16	Venango	Gresham silt loam	SP	D	WP, V	47	40
17-19	Crawford	Meadville gravelly s. l.	W	D	RP, NS, EL, WP	123	146
21-23	Erie	Platea silt loam	MW-SP	D	WP, NS, SP	82	89
26-29	Crawford	Venango silt loam	SP	D	RP, WP, NS, SP, JP	67	50
32	Butler	Gilpin channery loam	W	MD	SP, WP, V	58	130
33-34	Clarion	Sciotoville silt loam	MW	D	EL, YP, V	79	226
36-37	Clarion	Clymer channery loam	W	D	SP, WP, V	50	67
38	Potter	Lackawanna channery s. l.	W	MD-VD	RP, WP, V	103	394
39	Potter	Dekalb sandy loam	SE	MD	WP	77	30
40	Potter	Dekalb sandy loam	SE	MD	SP, WP	44	69

41	Potter	Dekalb sandy loam	SE	MD	NS, WP	71	68
43-44	Potter	Cattaraugus channery s. l.	W	D-VD	PP, EL, JP	93	85
46-47	Potter	Cattaraugus channery s. l.	W	D-VD	NS, WP, V	81	10
48	McKean	Ernest silt loam	MW-SP	D	NS, V	75	288
49	McKean	Ernest silt loam	SP	D	NS, V	48	52
50	Potter	Wellsboro silt loam	MW	D-VD	WP, V	114	138
51-54-56	Potter	Dekalb channery silt loam	W	VS-MD	RP, NS, EL, WP	112	223
52-53	Potter	Dekalb channery silt loam	W	VS-MD	WP, SP, EL	57	45
53A	Potter	Dekalb channery silt loam	W	VS-MD	SP, V	45	0
55	Potter	Dekalb channery silt loam	W	VS-MD	JL, WP, NS, V	95	282
55A	Potter	Dekalb channery silt loam	W	VS-MD	JL, WP	98	101
56A	Potter	Dekalb channery silt loam	W	VS-MD	WP, EL	67	24
57	Potter	Dekalb flaggy silt loam	W	VS-MD	SM, V	20	24
60-61	Potter	Oquaga silt loam	W	S	EL, NS, WP, V	53	20
63-65	Clarion	Gilpin shaly silt loam	W	S	WP, NS	56	120
64	Clarion	Gilpin shaly silt loam	W	VS	EL, V	91	278
66	Armstrong	Wharton silt loam	MW	D	NS, V	26	80
68	Armstrong	Gilpin-Montevallo s. l.	W	S	PP	18	0
70	Armstrong	Gilpin channery loam	W	MD	SP, V	36	49
71	Clarion	Cavode silt loam	SP-MW	MD-D	EL, WP, V	58	149

VOLUME AND YIELD

The yield in some of the plantations has been remarkable, and in many of them it has been eminently satisfactory (table 1). In four of the plantations, the yield exceeded 100 cubic feet per acre per year; seven plantations produced more than 1 cord peeled (92 cubic feet) per acre per year. In board measure, seven plantations had yielded more than 200 board feet per acre per year over the full age-span of the trees.

One outstanding plantation (No. 38) of red and white pines had a volume of 17,712 board feet per acre at age 45—a mean annual increment of 394 board feet! From age 30 to age 45, the periodic annual increment probably had exceeded 1,000 board feet (fig. 1).

Table 2 presents site-index, age, stocking, volume, and growth data by individual species in each plantation. Stocking and volume data are on an acre basis. Standing volume and total yield were identical, or practically so, in the 24 plantations that had not been thinned, and differed but little in the 7 lightly thinned ones. For the 6 plantations where more than 10 percent of the yield had been removed by thinning, the estimated volumes removed were:

Plantation No.	*Species*	*Volume removed*	
		Cubic Feet	*Board Feet*
5	WP	467	0
12	RP	647	2,020
39	WP	484	0
41	WP	1,004	0
48	NS	1,825	4,228
49	NS	861	1,060

It is interesting to note that 4 of the 7 plantations that produced over 200 board feet annually had never been thinned. Three of these unthinned plantations, including No. 38, were mixed plantings in which one species—either red pine or Japanese larch (fig. 2)—markedly outgrew the other planted species. This growth differential had acted like a well-timed gradual thinning, enabling the dominant trees to maintain rapid diameter growth.

Table 2.—Performance data, by species and plantation

Plantation number	Species	Site index	Age	Trees	Dominant and codominant trees	Basal area	Volume	Volume	Dominant and codominant trees			
									Mean d.b.h.	Mean annual diameter growth	Mean height	Mean annual height growth
		Feet	*Years*	*No.*	*No.*	*Square feet*	*Cubic feet*	*Board feet*	*Inches*	*Inches*	*Feet*	*Feet*
3	RP	73	36	138	86	37	679	568	8.0	0.22	52.8	1.47
4	SP	72	36	318	207	110	1,984	2,867	8.7	.24	54.9	1.53
5	WP	65	51	350	192	156	3,038	11,278	10.7	.21	61.9	1.21
	V	—	—	6	0	1	8	0	—	—	—	—
6	SP	68	39	407	274	122	2,080	307	8.3	.21	56.3	1.44
9	JL	73	46	293	205	112	2,467	4,655	9.2	.20	66.1	1.44
	V	—	—	146	44	40	670	0	—	—	—	—
12	RP	74	40	235	175	82	1,678	1,425	8.4	.21	57.2	1.43
13	WP	68	40	255	150	74	1,161	225	7.9	.20	49.0	1.23
14	PP	61	40	305	185	88	1,305	861	8.0	.20	49.6	1.24
	WP	—	—	5	5	5	119	555	—	—	—	—
15	JBP	64	39	594	388	177	2,580	1,748	8.0	.21	48.7	1.25
16	WP	56	43	620	360	150	1,930	1,720	7.6	.18	42.6	.99
	V	—	—	10	10	5	86	0	—	—	—	—
17	RP	79	43	525	391	193	4,823	5,623	8.8	.20	67.7	1.57
18	NS	—	43	44	—	2	0	—	—	—	—	—
19	EL	82	43	27	18	11	244	649	9.9	.23	74.0	1.72
	WP	—	—	9	—	2	44	—	—	—	—	—
21	WP	62	44	302	241	121	1,981	2,394	9.3	.21	52.3	1.19
22	NS	58	44	121	101	41	649	0	8.3	.19	51.4	1.17

CONTINUED

Table 2. — Continued

Plantation number	Species	Site index	Age	Trees	Dominant and codominant trees	Basal area	Volume	Volume	Dominant and codominant trees			
									Mean d.b.h.	Mean annual diameter growth	Mean height	Mean annual height growth
		Feet	*Years*	*No.*	*No.*	*Square feet*	*Cubic feet*	*Board feet*	*Inches*	*Inches*	*Feet*	*Feet*
23	SP	54	44	201	101	68	973	1,509	9.1	.21	47.8	1.10
26	RP	58	43	200	155	69	1,218	540	8.3	.19	49.8	1.16
27	WP	66	44	255	195	93	1,558	1,637	8.7	.20	52.9	1.20
28	NS	65	43	15	15	4	91	0	7.4	.17	56.3	1.31
29	SP	—	44	5	0	1	16	0	—	—	—	—
	JP	—	—	5	0	1	21	0	—	—	—	—
32	SP	71	48	275	165	94	1,941	3,845	9.0	.19	67.6	1.41
	WP	68	48	85	30	25	483	1,435	9.4	.20	63.5	1.32
	V	—	—	35	25	20	369	950	—	—	—	—
33	EL	86	53	151	105	87	2,205	7,109	11.0	.21	80.9	1.53
34	YP	83	53	130	80	59	1,538	3,747	10.4	.20	79.7	1.50
	V	—	—	15	5	5	75	0	—	—	—	—
36	SP	64	44	193	119	53	839	536	7.8	.18	54.8	1.25
37	WP	67	45	169	134	66	1,219	2,486	8.8	.20	55.9	1.24
	V	—	—	40	40	14	166	0	—	—	—	—
38	RP	72	45	285	165	173	4,198	17,712	12.1	.27	64.8	1.44
	WP	—	45	289	0	27	154	0	—	—	—	—
	V	—	—	35	30	17	268	0	—	—	—	—
39	WP	56	46	660	420	194	3,057	1,370	8.1	.18	49.3	1.07
40	SP	49	48	399	199	122	1,412	1,186	8.6	.18	42.0	.88
	WP	51	48	126	74	48	662	2,120	10.2	.21	46.1	.96

41	NS	60	46	259	123	58	917	1,580	8.1	.18	52.0	1.13
	WP	56	46	272	136	87	1,358	1,531	9.1	.20	48.1	1.05
43	PP	54	45	631	271	202	3,047	2,615	8.8	.20	49.6	1.10
44	EL	63	45	391	150	66	708	0	7.3	.16	59.0	1.31
	JP	—	45	30	30	19	420	1,202	10.4	.24	—	—
46	NS	58	46	253	166	42	489	383	6.1	.13	50.1	1.09
47	WP	55	46	1,046	584	219	3,061	82	7.1	.15	45.5	.99
	V	—	—	17	17	8	73	0	—	—	—	—
48	NS	70	54	110	110	92	2,214	11,330	12.3	.23	66.3	1.23
	V	—	—	14	0	3	4	0	—	—	—	—
49	NS	50	54	615	325	145	1,755	1,735	7.8	.14	42.0	.78
	V	—	—	0	0	0	0	0	—	—	—	—
50	WP	63	52	846	525	292	5,890	7,192	8.9	.17	61.1	1.17
	V	—	—	5	5	2	24	0	—	—	—	—
51	RP	71	44	364	284	156	3,654	9,432	9.3	.21	62.3	1.42
54	NS	70	44	301	91	43	780	364	7.3	.17	60.8	1.38
56	EL	69	44	45	5	6	58	0	6.8	.15	63.3	1.44
	WP	63	44	216	23	30	438	0	7.0	.16	54.0	1.23
52	WP	58	46	109	100	37	639	824	8.0	.17	52.1	1.13
53	SP	60	46	534	326	136	1,981	1,232	7.4	.16	48.6	1.06
	EL	—	46	9	0	1	0	0	—	—	—	—
53A	SP	58	41	835	288	153	1,662	0	7.6	.19	46.0	1.12
	V	—	—	58	58	13	202	0	—	—	—	—
55	JL	90	41	291	221	136	3,598	11,546	10.0	.24	76.1	1.86
	WP	—	41	441	0	45	298	0	—	—	—	—
	NS	—	41	5	0	0	0	0	—	—	—	—
	V	—	—	5	0	1	1	0	—	—	—	—
55A	JL	78	41	562	375	164	3,689	4,153	7.8	.19	63.5	1.55
	WP	—	41	562	0	45	343	0	—	—	—	—
56A	WP	56	45	698	547	155	2,377	1,075	6.6	.15	46.9	1.04

CONTINUED

Table 2. — Continued

Plantation number	Species	Site index	Age	Trees	Dominant and codominant trees	Basal area	Volume	Volume	Dominant and codominant trees: Mean d.b.h.	Dominant and codominant trees: Mean annual diameter growth	Dominant and codominant trees: Mean height	Dominant and codominant trees: Mean annual height growth
		Feet	*Years*	*No.*	*No.*	*Square feet*	*Cubic feet*	*Board feet*	*Inches*	*Inches*	*Feet*	*Feet*
	EL	63	45	358	245	52	632	0	5.5	.12	52.1	1.15
57	SM	53	64	146	129	65	1,248	1,535	9.1	.14	53.6	.84
	V	—	—	8	4	1	8	0	—	—	—	—
60	EL	72	46	294	164	72	632	768	7.9	.17	64.7	1.41
61	NS	65	46	275	60	41	400	0	7.3	.16	55.0	1.20
	WP	60	46	369	115	76	1,189	130	7.9	.17	54.4	1.18
	V	—	—	55	40	16	188	0	—	—	—	—
63	WP	60	46	390	265	138	2,233	5,169	8.9	.19	51.5	1.11
65	NS	60	47	183	50	26	342	340	7.3	.16	53.5	1.15
64	EL	84	46	315	207	150	3,535	12,021	10.4	.23	78.1	1.70
	V	—	—	99	33	30	640	753	—	—	—	—
66	NS	65	43	129	83	54	997	3,438	9.9	.23	52.2	1.22
	V	—	—	47	26	10	97	0	—	—	—	—
68	PP	45	43	436	244	74	774	0	6.3	.15	37.0	.86
70	SP	70	38	192	128	70	1,206	1,845	8.8	.23	53.4	1.41
	V	—	—	39	26	12	179	0	—	—	—	—
71	EL	80	47	150	85	72	1,637	5,807	11.0	.23	69.9	1.49
	WP	57	47	320	120	66	941	1,050	7.8	.17	48.0	1.02
	V	—	—	40	15	10	129	125	—	—	—	—

Figure 1.—A mixed red pine-white pine plantation (No. 38) that measured 17,712 board feet per acre of red pine at age 45—a yield of nearly 400 board feet per acre per year. This plantation, which was 50 years old when the photo was taken in 1965, was self-thinned through suppression of most of the white pine by the red pine.

Mixed plantings that did not produce such high board-foot volumes were either growing on less productive sites, were still fairly young, or had two or more species that grew about equally well, thereby failing to thin themselves. Nearly equal growth rates were well demonstrated in two mixed plantations on good sites involving Scotch pine. One was a Scotch pine-red pine mixture (fig. 3) and the other a Scotch pine-white pine mixture. In both, 70 percent of the trees were Scotch pine. Another plantation where mixed species grew at about the same rate was No. 12-13, which contained red pine and white pine.

Figure 2.—A group of mixed plantations in Potter County. The Japanese larch of plantation 55 can be seen left of the center of the photograph and the red pine of plantation 51 to the right of center. These species maintained rapid growth without thinning through the suppression of the white pine and other species planted among them.

Figure 3.—Mixed red pine-Scotch pine plantation (No. 3-4) exhibiting excellent, nearly equal height growth by the two species. Of the Scotch pine, 78 percent were straight trees, but 8 percent were spiral-shaped like the tree being measured here.

Two single-species plantations that had done remarkably well without thinning were European larch No. 64 and white pine No. 50. The larch had made good diameter growth because the trees were well differentiated, ranging from 4.7 to 13.1 inches in diameter, and the stand was not overstocked. Survival in 1939 was 25 percent, and our sample in 1961 showed 18 percent. The white pine plantation, even though dense (851 trees per acre) had not stagnated; diameters ranged from 4.1 to 11.9 inches. It had the highest cubic-foot volume (5,914) among all the plantations examined, and also had a good board-foot yield (7,192). Had it been thinned, this plantation no doubt would have produced an even greater board-foot yield.

SITE INDEX

Site index, expressed as total height in feet at age 50, was obtained for each species in each plantation, except where not enough dominant and codominant trees were available for a determination. There was a wide range in site-index values—from 45 for one planting of pitch pine to 90 for one of Japanese larch.

Soil characteristics and other site factors that influence site index are discussed later by species.

BASAL AREA

Knowledge of desirable levels of stocking in terms of basal area or number of trees at different ages is necessary for good plantation management. Although no controlled comparisons are available in this study, a record of the stocking of the better plantations should be helpful.

Basal areas ranged up to 294 square feet per acre. This maximum was recorded for the above-mentioned white pine plantation No. 50. This stand obviously needed thinning; but No. 38, with 217 square feet, did not appear seriously overstocked. However, the red pine overstory had 173 square feet, and it was reaching a point where thinning would help (fig. 1).

Several plantations in which the stocking appeared to be ade-

quate but not overly dense, and in which the dominant trees had attained good average diameters, ran around 130 to 160 square feet of basal area per acre either overall or in the dominant species. A majority of these plantations had mean annual increments of more than 200 board feet per acre; only one of them fell below 100 board feet. Basal areas and numbers of dominant-codominant trees per acre in this group of plantations are tabulated below:

Plantation number	*Principal species*	*Basal area (square feet)*	*Dominant and codominant trees (number)*
5	White pine	157	192
9	Japanese larch	152	249
12-13	Red pine-white pine	156	325
33-34	European larch-yellow poplar	151	190
38	Red pine	217 (173)	195 (165)
51-54-56	Red pine-Norway spruce-white pine	235 (156)	403 (284)
55	Japanese larch	182 (136)	221 (221)
64	European larch	180 (150)	240 (207)
71	European larch-white pine	148	220

Plantations 5 and 9 were pure plantings; all others were mixed, though all but one of the associated species in Nos. 38, 55, 64, and 71 appeared so suppressed in 1939 that they were not given plantation numbers. In the mixed plantings, values in parentheses are for species that definitely were dominant; no parenthesis means the two species were essentially codominant.

There were about seven plantations within the same basal-area range that definitely were overstocked. Four of these were on below-average sites. The sites for the other three plantations (Nos. 3-4, 32, and 36-37) were reasonably good, but in each case the two species in the mixture had grown at about the same rate.

In general, plantations with less than 100 square feet of basal area appeared to be understocked. Optimum stocking will of course vary somewhat among species; so each species should be considered separately. For example, Scotch pine is unable to maintain as much basal area as most other species. It appears that a good residual basal area for most species would be in the range of 100 to140 square feet, exclusive of suppressed and understory stems.

NUMBER OF TREES

The number of trees per acre ranged from 124 to 1,316; the high number was in a 46-year-old white pine-Norway spruce plantation. Numbers of dominant and codominant trees ranged from 109 to 792 per acre. Those plantations that appeared to be understocked, based on visual judgments of spacing and crown size, had 110 to 154 dominant and codominant trees per acre. The well-stocked ones had 190 to 325 dominant and codominant trees per acre and the obviously overstocked plantations had 200 trees and up—mostly over 250. The gap between the first two ranges of stocking figures and the overlap between the second and third ranges were a result of differences in species, age, and site of the plantations from which the figures were derived.

STEM FORM

Red pine, Japanese and European larches, and Norway spruce had excellent stem form. A simple average of the percentages of trees falling in the previously defined form classes follows for each planted species:

Species	*Stem form 1 (percent)*	*Stem form 2 (percent)*	*Stem form 3 and 4* (percent)*	*Plantations (No.)*
Red pine	74	22	4	6
White pine	29	27	44	12
Scotch pine	29	28	43	9
Pitch pine	37	35	28	3
Japanese black pine	56	23	21	1
Japanese larch	78	14	8	3
European larch	85	9	6	7
Norway spruce	79	5	16	10
Yellow-poplar	35	27	38	1
Sugar maple	66	6	28	1

*Predominantly stem form 3.

The figures for white pine include only the plantations where it was the principal species. Figures for the other species are based on data from all plantations where the species were well represented.

SOIL OBSERVATION

The pH values for the plantation soils ranged from 4.2 to 6.0. However, pH or soil acidity in itself did not appear to be a limiting factor for any species. Although height growth was comparatively poor in the plantations on highly acid soils (pH 4.4 or lower), soil drainage was either somewhat poor or somewhat excessive on all these sites, and is believed to have been largely responsible for the slow growth. This interpretation is supported by the fact that some of the best plantations were on soils of pH 4.5 or 4.6 where the soils also were well drained.

A large variety of humus types was encountered, but we could detect no relation between humus type and tree growth.

Site index-soil correlations are discussed under each species below. Soil drainage and depth designations are standard terms as defined in the U.S. Department of Agriculture Soil Survey Manual *(Soil Survey Staff 1951)*.

GROUND COVER

Volunteer tree seedlings and saplings were found in nearly all plantations. Black cherry, red maple, and white ash were recorded on 76, 65, and 54 percent of the sample plots, respectively, and may have been sparsely represented but not tallied on other plots. One or more species of oak were listed on 30 percent of the plots. Briars (*Rubus* spp.) were the most common shrub. Ferns occurred on 40 percent and grasses on 24 percent or more of the plots. *Maianthemum* and *Mitchella* were the next most common herbs. Some of the plantations have excellent prospects for conversion to hardwood stands.

SPECIES EVALUATIONS

Red Pine

Red pine was present on plots in six plantations. It was an outstanding performer, the chief component in plantation 17-19, which had the highest mean annual increment in cubic feet, and in No. 38 (fig. 1), which had the highest mean annual increment in

board feet. It was represented among the dominant trees wherever it had been planted. Average annual diameter growth of dominant and codominant trees on the six plantations was 0.22 inch, and average height growth was 1.40 feet.

The well known requirement of good soil drainage for red pine was substantiated in this study. Site indexes ranged from 58 to 79 feet, with a mean of 71, and showed a distinct correlation with soil drainage. Five of the six red pine plantations were on well-drained soils and showed site indexes of 71 or better; the other was on a level, somewhat poorly drained soil, and here the site index was 58. Another plantation (No. 21-23), on a level and moderately well to somewhat poorly drained soil, had a few red pines outside the plot and here again the site index for this species was low—59 feet. The best site index, by 5 feet, was on a deep, well-drained Meadville gravelly silt loam. However, not all good sites were deep soils. On one such site the soil was moderately shallow and on a steep slope, but on a northwest aspect. Another was not more than moderately deep and faced southeast.

The mean annual rate of height growth by red pine had held up well at around 1.4 feet during the 21 years since Hetzel's measurements in 1939, but diameter growth had dropped from the relatively high rate of 0.28 inch per year in 1939 to 0.22 inch as the stands aged (fig. 4).

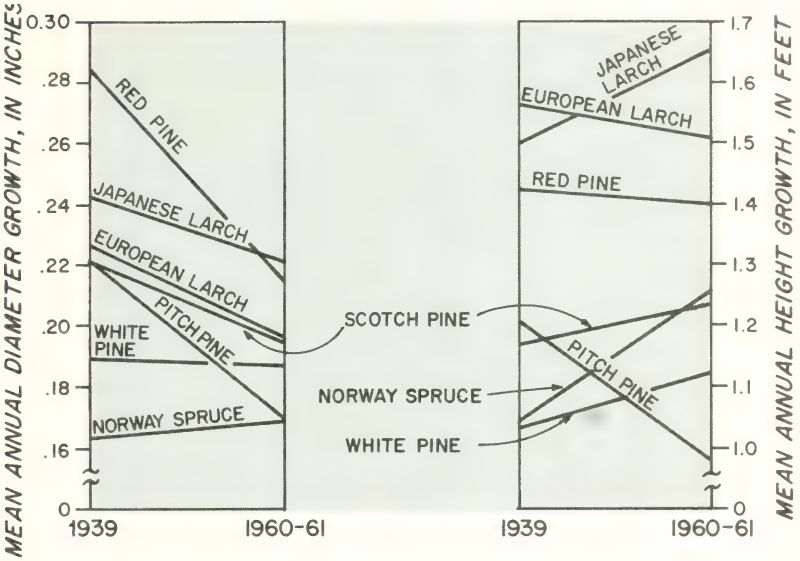
The form of red pine stems was excellent. In all but one heavily damaged plantation, 78 to 100 percent of the red pine trees were straight for their entire length. In four of the six plantations that contained red pine, 100 percent of the red pines were in stem-form classes 1 and 2.

The only damage noted on red pine was in plantation 26-29, where Hetzel recorded top breakage caused by roosting starlings before 1939. None of the red pines in this plantation were rated stem-form 1.

Eastern White Pine

White pine was the most widely used species. It had been planted in 22 of the 37 plantations and was still represented in the dominant and codominant crown classes in 18 of them. It has done

Figure 4.—Changes in mean annual diameter and height growth for the seven best represented species, 1939 to 1960-61. Pitch pine and Japanese larch were represented by 2 plantations each, other species by 5 to 10 plantations each.



well in several instances despite varying degrees of weevil damage. In one of the few well-thinned plantations (No. 5, fig. 5), white pine had produced 221 board feet per acre per year. One unthinned plantation (No. 50) had a mean annual increment of 114 cubic feet.

White pine lost out to red pine where the two species were planted in mixture on well-drained soils; in two instances the white pine site index was 6 to 8 feet lower. The reverse was true on a somewhat poorly drained soil; here the white pine site index was 8 feet higher than for red pine. White pine had also fallen behind Japanese larch in mixtures, but had held its own with Norway spruce. It had grown well on some, but not all, soils classed in the range of somewhat poorly drained to well-drained. The mean site index for 16 plantations where white pine was fairly well represented in the dominant-codominant crown classes was 61 feet.

Figure 5.—White pine in one of the few well-thinned plantations (No. 5). At age 51, it had produced 221 board feet per acre per year.

Almost all plantations had been damaged, in varying degrees, by the white-pine weevil. The close spacing that was always used in planting *(Hetzel 1941)* was fortunate because it usually resulted in enough well-formed trees to meet stocking requirements for crop trees.

Presumably the white pine in several of the mixtures developed better than appeared likely in 1939. In four plantations where Hetzel did not measure the white pine, dominant and codominant trees were found on our plots. In two of the four plantations he noted that the white pine was heavily weeviled and very poor; but he predicted that a fair crop might be brought through. In another of the plantations where he did not measure the white pine, a Scotch pine-white pine mixture (No. 32), he noted that the white pine was almost a complete loss. Yet, at the time of our survey, white pine made up nearly one quarter of the sawtimber volume on the sample plot.

Pine bark aphids were observed in at least four plantations but had caused no mortality. Recent top breakage, obviously caused by ice, had occurred in one plantation. Hetzel had noted top damage in two others.

Surprisingly, the diameter growth of white pine dominant and codominant trees had held up at 0.19 inch annually through the 1939-61 period (fig. 4), even though only two of the stands had been thinned. Height growth had increased from 1.03 feet annually as of 1939 to 1.12 feet at the time of our survey. This may have been due to a reduction in weevil injury with increasing height of the trees.

Scotch Pine

Scotch pine had not shown high volume production, compared to some of the other species, on any of the nine plantations where it had been planted. The seed sources are unknown. Height growth was good on four plantations (site index 68 to 72). Three of these four plantations were 36 to 39 years old and may be expected to increase their board-foot production considerably by age 50. On the seven plantations where comparison with Hetzel's figures was possible, the mean annual height growth of dominant and codom-

inant trees apparently increased, on the average, from 1.17 to 1.23 feet between 1939 and 1960-61. The mean annual diameter increment fell slightly, from 0.22 to 0.20 inch (fig. 4).

Average site index for the nine Scotch pine plantations was 63 feet. On well-drained soils the site index was 58 or better. However, it was lower on a moderately well to somewhat poorly drained soil and still worse on a moderately deep, somewhat excessively drained Dekalb sandy loam.

There was a marked tendency for Scotch pine on good sites to have better-than-average form (fig. 3). For all nine plantations, 58 percent of the trees were tallied stem-form 1 and 2, but in the four plantations where the site index was 68 or better, 74 percent of the stems were stem-form 1 and 2. Yet provenance tests have shown that the fastest growing sources tend to have the most bole defects *(Wright and Baldwin 1957)*.

Some mortality, of undetermined cause, was observed in plantations 36-37 and 70. No other significant damage or pests were noted.

Scotch pine stands typically have a comparatively thin, open canopy, which permits an abundance of understory plants to develop. Compared to the growth under other heavier-foliaged species, the ground cover in the Scotch pine plantations was outstanding. The two pure Scotch pine plantations had especially lush ground covers of herbs, shrubs, and tree seedlings and saplings. In one of these stands, 31 species of woody plants were found on one 0.12-acre plot. The contrast in understory growth was strikingly demonstrated in an area where one of the pure Scotch pine plantations bordered a white pine plantation; there the latter was nearly devoid of ground cover, while the Scotch pine had a profuse understory of young hardwoods (fig. 6).

This and similar understories demonstrate the value of Scotch pine as a nurse crop for native hardwoods—a value that has also been noted by Littlefield *(1949)*, Hough *(1958)*, and Wright and Bull *(1963)*. Perhaps Scotch pine, deliberately selected for the purpose, might have an important place in re-establishing hardwoods on old-field sites. The lower timber yield of the

Figure 6.—Adjoining white pine and Scotch pine plantations showing excellent hardwood regeneration under Scotch pine in the background, in contrast to the practically bare forest floor under white pine in the foreground. The white pine plantation had just been thinned when this photo was taken.

Scotch pine, as compared to certain other conifers, might be more than compensated for by the accelerated succession to hardwoods.

Pitch Pine

Pitch pine had done very poorly; we found nothing to recommend it. On the three plantations where it was planted, its site

index averaged only 53. It was planted on a good range of soils—shallow, well-drained; deep, well-drained; and deep, poorly drained. Oddly, its best height growth and by far the best form were on a poorly drained slope. But there were gaps in the wet spots and mortality was taking place around the edges of them.

Japanese Black Pine

There was one plantation of this species (No. 15) on a deep, moderately well-drained Titusville silt loam (fig. 7). Its age was 39; average height was 49 feet; and average diameter of dominant-codominant trees was 8.0 inches. No thinning of any consequence had been done; basal area was 177 square feet per acre. The trees seemed to have accelerated in diameter and height growth since 1939. The plantation was in good condition and, although some trees were forked, 56 percent of them were stem-form 1. The trees and stand looked like red pine. This species is worth further testing under various site and climatic conditions.

Jack Pine

Jack pine was represented only by single trees on or next to plots in three plantations. They had maintained dominance on deep well-drained soils, but had lost out on a somewhat poorly drained site. On the Meadville gravelly silt loam of plantation 17-19, which was the best red pine site, two jack pines averaged 71 feet feet in height at age 43. But Hetzel's plantation 69, on a shallow, well-drained soil, had died out completely since 1939. Some of the remains could still be found on the ground but the cause of failure is unknown.

European Larch

European larch had performed very well in several places, producing over 12,000 board feet per acre in 46 years in plantation 64. Mean annual increment was 278 board feet in this plantation and, including some intermixed yellow-poplar, 226 board feet in plantation 33-34. Cubic-foot volumes were not as high as for some other species because the larch was usually in mixtures, or in stands not fully stocked with it, and because larch requires wider spacing

Figure 7.—The 39-year-old Japanese black pine plantation 15 in Venango County.

than red and white pines or spruces. Height growth was excellent on good sites. There was a wide range in site index—from 63 to 86 feet, averaging 75 feet. The tallest tree in all these plantations was a European larch in No. 33-34 that measured 94 feet at age 53.

This larch species had done well on two moderately well-drained soils and on two well-drained ones. Four sites of below-average quality also involved well-drained soils. These soils were of various depths and the moisture supply may have differed considerably among them. This could have accounted for the differences in tree performance. The four below-average sites were on 31- to 47-percent southeast or southwest slopes. Of the two well-drained sites that were above average, one (plantation 64) had a very shallow soil but lay on the lower part of a gentle northwest slope. The other (plantation 17-19) was on a steep but very short northeast slope with a large level till area behind it and seepage at the base. This mixed plantation was predominantly red pine and the red pine site index here (79 feet) was the highest among all the red pine planting sites. Nevertheless the pine was being outgrown by the scattered European larch, which seems to be especially favored by moist sites. On drier slopes, red pine will usually outgrow the larch.

Mean annual height and diameter growth rates had held well, declining only slightly between 1939 and 1960 (fig. 4). Stem form was excellent, 85 percent of the trees being classed as stem-form 1.

No pests were noted, but a few of the larches in plantation 33-34 had suffered top damage from ice or snow when about 25 feet tall.

Japanese Larch

There were only three plantations of this species, two of them in the same locality. It had done very well. In two of the plantations the mean annual increment was 101 board feet, and in the third it was 282 board feet per acre. Cubic-foot production was also high in the two plantations (Nos. 55 and 55A) where it had been planted in mixture with white pine. Plantation 55 especially (fig. 2) is a fine example of a mixed planting in which suppression of one species resulted in a thinning and the release of the domi-

nant species. At only 41 years of age the volume was 11,500 board feet per acre.

Site indexes for Japanese larch were 73, 78, and 90 in plantations 9, 55A, and 55, respectively. The highest index measured for any species was 90, but even 73 could hardly be called low. Plantations 55 and 55A were both on Dekalb channery silt loam, a well-drained soil that may vary from very shallow to moderately deep. The slope was 40 to 45 percent and faced southeast. The difference in site index expressed on the two plots was surprising since the two plantations were adjacent to each other. Plantation 55A was just above No. 55 and its soil may have been shallower or dryer.

This larch also had grown well in plantation 9, where the soil was poorly drained, at least in spots, along a brook. However, the stocking was irregular because of low survival and ice damage in the winter of 1938-39. Twenty to 40 percent of the crown area was occupied by volunteers.

Plantations 55A and 56A provide an interesting comparison of European and Japanese larches growing on a dryish site. The two plantations were just a few feet apart and at comparable positions on the slope. Both were larch-white pine mixtures. In No. 55A, Japanese larch was completely dominant over the white pine; its site index was 78 feet. In No. 56A, European larch was represented in the upper canopy by only a few codominant trees; its site index was 63 feet and the white pine was dominant.

It was not possible to compare the two larches on moister sites. However, Aird and Stone *(1955)* reported that Japanese larch made the greater height growth in soils of corresponding depth and drainage. It also gives a greater yield in young plantations in Great Britain *(Brit. Forestry Comn. 1938).* Hummel *(1949)* stated that Japanese larch is superior to European larch in height growth and volume production in Great Britain, and that height growth of Japanese larch does not fall off as much in later years as had previously been assumed.

Japanese larch in these plantations maintained its diameter growth well, and increased its rate of height growth between 1939

and 1961 (fig. 4) Like European larch, it displayed excellent stemform, except in plantation 9 where ice damage had occurred. No evidence of pest damage was seen.

Norway Spruce

Only one of the 10 plantations where the sample plot contained Norway spruce was outstanding. However, only 2 of the 10 plantations were well-stocked pure Norway spruce. No. 48, a pure plantation that had been thinned at least twice, had a stand volume of 11,300 board feet and an estimated yield of 15,500 board feet per acre at age 54. This was a mean annual increment of 288 board feet per acre. Norway spruce was most often planted in mixture, usually with white pine alone, but in three cases with a third species. In these mixtures the spruce tended to supplement the stocking and volume of the stands. It usually made up about 15 percent of the cubic volume.

Site index ranged from 58 to 70, with a mean of 63 feet, not including a badly weeviled plantation. This is a narrow range compared to other species. The outstanding plantation 48 (site index 70) is at the bottom of a slope on a deep, moderately well to somewhat poorly drained Ernest silt loam. Equally good height growth was made on a shallow to moderately deep, well-drained soil (No. 51-54-56).

Average site index and annual height growth of Norway spruce were the same as for Scotch pine, better than for white pine, and poorer than for the other common species. Norway spruce and other spruces are well known to be slow starters. This was evident in these plantations. Many of the spruce trees fell behind and became suppressed, but those that were still in a codominant position in 1960-61 should maintain their dominance. Their leaders were long and vigorous. Some of the intermediates seemed likely to become codominant. In 1939 the mean annual diameter and height increments of dominant and codominant spruces on nine plantations averaged 0.16 inch and 1.04 feet respectively. The average age then was 26. In 1960, at age 47, the respective values were 0.17 inch and 1.25 feet (fig. 4). This means that the trees had grown 1.50 feet in height annually since 1939. These figures are

simple averages for nine plantations—not weighted by numbers of trees.

The form of Norway spruce was good on the whole, and excellent in several plantations. The average proportion of stems classed as stem-form 1 was 79 percent. In three of the plantations, 100 percent of the sample-plot trees were stem-form 1, and in two others 99 or 100 percent of the trees qualified for stem-form 1 or 2.

One plantation of pure Norway spruce (No. 49) was badly weeviled and some possible weevil damage was noted in one mixed plantation. In plantation 66 some mortality of unidentified cause had occurred and, both before and after 1939, there had been some cutting thefts for Christmas trees.

Planted Hardwoods

Our survey included only two plantings of hardwood species: yellow-poplar in mixture with European larch in No. 33-34 and pure sugar maple in No. 57. This was hardly enough basis for drawing any conclusions, except perhaps that yellow-poplar can grow well. This species was planted on an admittedly good soil—Sciotoville silt loam. Its site index here was 83 feet. In spite of the excellent growth of the intermixed European larch, the yellow-poplar made up about 40 percent of both the basal area and the dominant and codominant trees, and about one third of the volume. The form of the yellow-poplar was good for planted hardwoods: 62 percent of the trees were stem-form 1 or 2.

The sugar maple plantation was very poor. Even though sugar maples were growing in the woods above this plantation, the site was probably too dry or too low in nutrients for good sugar maple growth. The soil was Dekalb flaggy silt loam, a very shallow to moderately deep, well-drained soil—in this case on a steep southeast slope. Wild saplings 8 to 10 feet tall had been planted in a 16-by-20-foot spacing. Although survival was excellent, the crowns had not closed by 1939. Hetzel estimated the age at that time as 42 years.

White ash and red oak also had been included in some of the plantings in Potter County, where the sugar maple and several other plantations were located. These were Hetzel's plantations 58,

59, and 72. Neither of these species had formed a stand, being either edge trees or scattered individuals among other species. Both form and growth rate of the white ash were poor. The red oak had done better. A group containing five dominant and codominant oaks grew next to Scotch pine plantation 53A. They were taller and straighter than the pine and, in fact, were taller than the white pine, Scotch pine, and European larch in other nearby plantations. The average diameter and height of dominant and codominant trees at age 37 was 8.7 inches and 58.2 feet. This was a healthy mean annual height growth of 1.57 feet.

Volunteers

About half of the sample plots contained vounteer hardwoods or white pines over 4.5 inches in diameter.

Black cherry was the most important species both in abundance and cubic volume. Red maple, red oak, white ash, and aspen were fairly common. Age was not determined, but the larger trees on sample plots should have been about the same age as the plantations. Large old residuals were avoided in locating plots. For the 18 plantations where volunteers were present, the average volume of the volunteers was 178 cubic feet or 102 board feet per acre. This of course was a bias on the low side because plots were selected in uniform portions of the plantations.

Form of the trees was generally poor. Only 11 percent of the volunteers in the average plantation were stem-form 1 and 18 percent stem-form 2. The proportions of trees in stem-form classes 1 and 2 to those in 3 and 4 were about the same among diameter classes and among crown classes. One might expect that small trees or trees with intermediate crowns would have better stem-form than large dominants, but such was not the case.

SPECIES COMPARISONS

In site-index values and volume growth, red pine, Japanese larch, and European larch excelled all the other species. Norway spruce and white pine ranked considerably lower in site-index values, but nevertheless were making fairly good volume growth. Scotch pine ranked about equal to the spruce and white pine in

site-index values; but, at least in part because of younger average age (39 years), volume growth of the Scotch pine was comparatively low. Pitch pine ranked lowest among the seven principal species in every respect (fig. 8).

In comparing species, the mean and maximum values are more significant than the minimums. A maximum value shows what a

Figure 8.—Ranges of values for site index and mean annual increments for the seven principal species. Lines across the horizontal bars denote mean values. Volume increments for any one species were based on only those plantations in which that species comprised 80 percent or more of the cubic- or board-foot volume.

species is capable of doing, while a minimum value may represent an off-site plantation or, as regards volume increments, a very poorly stocked plantation. Board-foot volume growth is a better indicator of value increment than cubic-foot volume, but the latter depends less on age and spacing.

PURE vs. MIXED PLANTATIONS

In these plantations we have seen some excellent results in mixed plantations, even where no thinning had ever been done. Plantation 38, a red pine-white pine planting, and No. 55, a Japanese larch-white pine mixture, are the best examples. No. 38 contained 17,700 board feet of red pine at age 45, and No. 55 contained 11,500 board feet of Japanese larch at age 41 (figs. 1 and 2). In both, the white pine dropped into a subdominant position, thus releasing the other species, as in a well-timed thinning. Plantation 51-54-56 was another in which this happened. This was a four-species mixture by single rows of red pine, white pine, Norway spruce, and European larch. By 1960-61 most of the larch had died out and the white pine and spruce were in the understory. This plantation had about 9,400 board feet of red pine and 400 board feet of spruce per acre at age 44 (fig. 2).

Not all the mixed plantings resulted in suppression of all but one species. Yellow-poplar made up about a third of the 12,000 board feet per acre in plantation 33-34, where it was planted in good soil with European larch. Scotch pine kept up with red pine in No. 3-4 and with white pine in No. 32. White pine and Norway spruce grew well together in several plantations. Plantation 60-61 was a mixture of three species by double rows; and this pattern, as compared with a single-row pattern, helped each species to maintain itself in the mixture.

Of the pure plantations, only those where the stocking had been reduced by thinning or natural mortality had done well in board-foot volume growth. Three of the seven plantations that produced over 200 board feet per acre annually had been pure plantings. These were No. 5 (white pine), No. 48 (Norway spruce), and No. 64 (European larch). The first two were well-thinned. In No. 64 the stocking was low; Hetzel estimated survival in 1939 to be

only 25 percent. Hardwoods had filled the gaps and made up 17 percent of the basal area in 1960-61.

Discussion & Recommendations

One disadvantage of this type of study is that we have no knowledge of the plantations that failed completely. Nevertheless we could study the performance of several species on a considerable range of sites, and compare the results with earlier measurements.

Hetzel in his report recommended red pine over other commonly planted species on open upland sites in this area. On frost-free sites, he said, the larches also offer promise of rapid and successful development. He added that red pine and Japanese larch were superior in a rating based on form, height growth, and diameter growth, followed by jack pine and pitch pine, which he indicated could be used with reasonable assurance of success. He also listed Norway spruce as a useful species. Hetzel placed white pine at the bottom of his rating of eight species and Scotch pine just above it.

Based on our study, and assuming that species will be matched to suitable sites, red pine is still to be recommended, with Japanese and European larch very nearly equal to red pine and to each other. Red pine should be used on the drier, well-drained sites, and the larches on moderately well-drained or slightly wetter soils. Both red pine and the larches will do well on moist, well-drained soils.

These plantings gave no basis for recommending pitch pine. Perhaps jack pine did not have a fair trial here, but certainly nothing about its performance recommended it for production of sawlogs. For both of these species, measurements of older plantations led to different conclusions than those based on earlier measurements.

Another change in ranking occurred in white pine, which improved its position after the 1939 measurements. We consider it fourth on the list now. Norway spruce can still be rated a useful species. Scotch pine, while generally poor in yield thus far, has

shown some promise. Selected progenies may have use, particularly in the warmer portions of the region where the shoot moth causes severe damage to red pine. Scotch pine, as pointed out by Miller and Heikkenen *(1959)*, is damaged less by the shoot moth than red pine. Moreover, Scotch pine plantations may have value for purposes other than timber production in that they create conditions favorable for hardwood regeneration.

Not enough hardwood plantings were available for examination to justify any definite conclusions about performance of different hardwood species. However, a few plantings of yellow-poplar and red oak indicated that these species are capable of growing well on suitable sites.

Besides inherent growth characteristics, susceptibility to pests will influence the selection of species to plant. The two major pests of our planted trees are the white-pine weevil and the pine shoot moth on red pine. Both of these insects may attack certain other tree species besides the principal host, but the damage inflicted on these other species is spotty and usually less destructive.

In the present plantations, white pine did surprisingly well under weevil attack—considerably better than Hetzel expected in 1939. In fact, white pine could be an outstanding species in this region if a moderate effort were expended on weevil control. Heiberg *(1953)* reported that white pine in New York will overtake red pine in height growth at 40 to 50 years of age. This may yet happen in some of the red pine-white pine mixtures in northwestern Pennsylvania.

The pine shoot moth is not a serious pest on red pine at the higher elevations of northwestern Pennsylvania. It tends to be more damaging at lower elevations and southward as the climate becomes milder, and here some discrimination against red pine might be warranted. In Michigan, Heikkenen and Miller *(1960)* reported that red pines growing 15 inches or more per year in height were resistant to attack. All the red pine plantations on well-drained soils in our study exceeded that growth rate; those on somewhat poorly drained soils fell short of it.

Another factor that may have some influence on the selection of species to plant is their utilization value. However, this will usual-

ly be a secondary consideration; no great decisive differences in utilization potential exist among the coniferous species growing in the study plantations.

These plantations have shown the value of planting intimate mixtures for the purpose of natural or self-thinning. Where self-thinning took place through the suppression of one species by another, it made noncommercial thinnings unnecessary, prevented serious overstocking for the first 40 years or more, and improved the sawlog yield.

Although well-timed selection thinnings on a crop-tree basis would be preferable to self-thinning, these pre-commercial treatments are frequently not practical or economical. For this reason, small private plantations would be especially suitable for mixed plantings. Although wide initial spacings might also be used to avoid early thinning, trees grown under these conditions tend to become extremely rough and have excessive taper.

Intimately mixed plantations also afford some insurance against planting the wrong species on a particular site. The species best adapted to the site will ordinarily displace less well-adapted species and become dominant. But even as we learn more about the site requirements of each species, there will still be some uncertainty as to which one will thrive best in a particular location. And there often are many site variations in a small area that would be difficult to define and treat individually.

The self-thinning advantages of intimate mixtures have scarcely been mentioned in the literature. Skog *(1951)* observed that suppression of white pine by red pine in 25-year-old mixed plantations apparently served the same purpose as thinning and that additional thinning was not needed to maintain the good red pine growth rate. Where row mixtures are used in plantations in Maryland, one species is often regarded as a filler. Some of these fillers have been harvested as Christmas trees; others serve as trainers and then die or are removed in thinnings *(Soc. Amer. Foresters 1961)*.

Intimate mixtures have often been judged failures in the past because one of the basic criteria set up for success was that the different species survive and grow at approximately the same rate.

If one rejects this criterion and judges success on a basis of total growth in volume or value, he will find mixtures offer substantial advantages over single-species plantings where precommercial thinnings are impractical. If precommercial thinnings are avoided, the chances for making the planting investment a profitable one should be greatly increased. For most situations, the planter will find the combination of red pine or larch (or both) with white pine or Norway spruce is a good one.

Summary

Plantations in northwestern Pennsylvania examined and measured by Hetzel in 1939 were revisited by the author in 1960 and 1961. At this time the average age of all plantations was 45 years. In our re-examination, measurements of height and diameter, and estimates of form of individual trees were made as in 1939; in addition, sample plots were laid out to obtain data on yield.

In some plantations where two or more species had been planted in mixture, one species became dominant and the other, or others, died out or were suppressed. This demonstrated one important advantage gained by using intimate mixtures in plantations that were not destined for precommercial thinning: the plantations had thinned themselves naturally. Another advantage is that mixtures increase the chances of having at least one species in a plantation that is well adapted to the site. Therefore, it would seem that mixed planting deserves more consideration.

The differing performance expressed after 20 or 21 more years' growth, together with the addition of yield data, resulted in some changes in ratings of the several species planted in this area. As in 1939, red pine and the larches were still the leading species in growth and yield, but pitch pine and jack pine had slipped to a point where they could no longer be recommended. White pine looked better than it had 20 years earlier, and would be an outstanding species if weevil control were practiced in the younger plantations. Norway spruce retained its rating as a useful species. Although Scotch pine was favored over white pine in the earlier study, it appeared in 1960-61 to merit planting only in certain special situations.

Growth and yield of some of the plantations has been remarkable, and in many it has been eminently satisfactory. Seven of the 37 plantations produced more than 1 cord (92 cubic feet) of peeled wood per acre per year, and 7 plantations yielded more than 200 board feet per acre per year over the full age-span of the trees. Thirty of the 37 plantations produced more than a half cord of peeled wood per acre per year. Height growth of the dominant and codominant trees in almost all plantations averaged over 1 foot per year. Diameter growth of the dominant and codominant trees in many of the plantations averaged over 0.20 inch per year.

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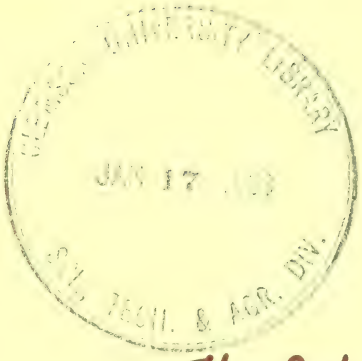
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The Role of CUSTOMER SATISFACTION in Managing Commercial CAMPGROUNDS

by Wilbur F. LaPage

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The Role of CUSTOMER SATISFACTION in Managing Commercial CAMPGROUNDS

■

The Formula

THE FORMULA for a successful private campground is deceptively simple. It is the same as that for any other highly competitive enterprise: satisfied customers. This relationship between the satisfied customer and the successful seller is so obvious that it almost sounds like a slick phrase. But I want to show you that this is a very real relationship; and then we can go on to consider a more profitable topic: how you can find economical ways to create customer satisfaction.

What Is Success?

First, what is commercial campground success? A few people have actually admitted to going into the campground business for the sole purpose of losing money. To succeed, they must fail. One of these owners plowed so much money into his campground that it became widely popular and was a resounding "success", in spite of his motives. So, if success has anything to do with managerial goals, he failed.

There is another kind of owner, who isn't exactly trying to lose money. To him the campground is a sort of hobby, an opportunity to manage something and to entertain people, as well as an excuse to buy expensive toys like tractors, chain saws, and public-address systems. "Success" is easily achieved for these people. For those campground owners who either want to lose money, or don't care about making money, my analysis of enterprise success is no doubt going to sound very shallow and unimaginative.

Success in the campground business involves—among other objectives—two basic goals: (1) to capture new customers, and (2) to stimulate longer and more frequent visits by old customers. These are the goals; how you achieve them is a critical element of success. You can *attract* new customers, but you cannot capture them without working through the intermediate step of creating camper satisfaction. There are many ways to *promote* longer visits, and repeat visits; but you will not *stimulate* these visits unless campers are satisfied.

Both of these goals can be measured in a number of ways that reflect the idea of camper satisfaction. For example, it is relatively easy to identify things like (1) the number of word-of-mouth contacts among new visitors, or (2) the number of new visitors who intend to return for a future visit, or (3) the difference between planned and actual visit lengths, or (4) the frequency of visits per year among established customers. Now, if we in our research can also develop a realistic measure of camper satisfaction, and correlate it with some of these attendance measures, the cash value of camper satisfaction should

become apparent. And this is precisely what we did in a 1961 study of campers at one of New Hampshire's larger state parks.[1]

In this study, over 300 campers were asked to evaluate their visit satisfaction on a four-point scale: highly satisfied, well satisfied, satisfied, and dissatisfied. The most we can say about this scale is that people at one end of it were more pleased with their visit than people at the other end. We don't know how much satisfaction increases with each step of the scale. But the scale was apparently meaningful to campers; and their camping satisfaction was closely related to their length of visit (tables 1 and 2), and to their intentions to return for a future visit (table 3). Those relationships shown in the tables pro-

[1]THE 1961 BEAR BROOK STATE PARK CAMPER SURVEY. An unpublished report in the files of the Northeastern Forest Experiment Station, Research Project FS-NE-1901. 47 pp., illus., 1963.

Table 1.—*The number of camper-groups at each of four satisfaction levels, and the corresponding number of days camped beyond their original plans*

Satisfaction level	Campers	Group-day surplus*
	No.	*Days*
Highly satisfied	100	45
Well satisfied	141	64
Satisfied	54	2
Dissatisfied	13	−8

*Sum of deviations between planned and actual visit lengths.

Table 2.—*Average visit lengths of camper-groups at each satisfaction level*

Satisfaction level	Length of visit
	Days
Highly satisfied	4¼
Well satisfied	3¼
Satisfied	3¼
Dissatisfied	1½

vide convincing proof that an effort to increase camper satisfaction can have both an immediate and a long-range pay-off.

On the average, campers whose expectations were "satisfied" stayed exactly as long as they had planned to stay (3 days), while those who were dissatisfied reduced their planned visit by 1 full day. Campers who were more than satisfied with their visit tended to stay an extra day, paying a bonus of $218 in campsite rental fees.

The long-range effects of camper satisfaction are even more impressive, even if only a fraction of the camper's plans to return ever materialize. And the word-of-mouth advertising of highly satisfied campers may well provide replacements for those who fail to return. The fact that these figures are drawn from a sample of only 308 campers shows how easily these bonuses could add up to several thousand dollars over a full camping season.

More and Longer Visits

The knowledge that camper satisfaction leads to longer and more frequent visits—that campers are rational consumers—led to a more detailed study, in 1964, of the camper and campground characteristics that are most commonly associated with long and frequent visits.

In this study we looked at some of the ways in which 37 "successful" private campgrounds differed from 48 "unsuccess-

Table 3.—*Percent of camper groups at each of four satisfaction levels who plan to return for a future camping visit*

Satisfaction level	Plan to return
	Percent
Highly satisfied	84
Well satisfied	60
Satisfied	56
Dissatisfied	23

ful" ones. Besides finding significant differences in campground ages, sizes, locations, investments, and attractions, we also learned that the average visits at the successful enterprises were longer ($4\frac{1}{2}$ days) than those at the unsuccessful ones (2 days).[2] This led to a more intensive analysis of the length and frequency of visit patterns of over 1,000 private campground visitors in 1964,[3] which re-affirmed the importance of campground characteristics to success, while disclosing several important characteristics of the campers themselves. The things that influenced visit length and frequency were camper's equipment, their past camping experience, and their preference (or lack of preference) for privately owned and operated campgrounds.

In examining the question of camper preference for private campgrounds, it became apparent that the public and private developments had contrasting images. Private campground visitors tended to view public campgrounds as being more crowded, and less restful; more primitive, with fewer conveniences; as having outstanding scenery, but few activities; and a more aloof management with poorer maintenance. The possibility that these images might reflect important differences in the interests and needs of patrons at these two types of campgrounds led to further studies in 1964, 1965, and 1967.

During the summers of 1964 and 1965 we began a long-term study of the differences in leisure behavior and annual camping participation of matched samples of about 850 public and private campground visitors.[4] And finally, during this past summer, we interviewed over 700 campers at New Hampshire state parks to find out how camping fees, and attitudes toward fees, influence camping frequency and the selection of campgrounds.

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[2]LaPage, Wilbur F. Success of Campgrounds Studied as Guide to Recreation Planners. U.S. Forest Serv. Res. Note NE-43. 7 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa. 1966.

[3]LaPage, Wilbur F. Successful Private Campgrounds: A Study of Factors That Influence the Length and Frequency of Camper Visits. U.S. Forest Serv. Res. Paper NE-58. 22 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa. 1967.

[4]La Page, Wilbur F. Camper Characteristics Differ at Public and Commercial Campgrounds in New England. U.S. Forest Serv. Res. Note NE-59. 8 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa. 1967.

This series of five studies,[5] along with several others done in recent years by different planning, research, and educational agencies, must qualify New Hampshire campers as among the most exhaustively studied groups of recreationists in the Country.[6] From all these studies we can now tie this research together into an orderly sequence and develop a general picture of what we have learned about the second goal of campground success—promoting longer and more frequent visits.

What We Think We Know

A model for a successful campground is illustrated in figure 1. The raw materials—the camper, the campground, and managerial attributes—interact to produce camper satisfaction. However, our understanding of how each of these variables operates is not as complete, nor as uniform, as the figure seems to indicate. For this reason a brief statement of just what we do know—or think we know—about each of these variable seems like a logical place to begin.

Each of the following findings should be qualified by the addition of a probability statement, and by reference to the time and place where the studies were made. For example, the finding that "campers who use highly mobile camping equipment do not stay as long as tent campers", reads like a universal principle because the qualifying phrases of "on the average", "in New Hampshire", and "during the early 1960's", have been left off. For another time and place where campers do not use tents, for example, the statement is totally meaningless. And please understand, at the outset, that practically every one of

[5]The research described above was carried out in several distinct studies, which were not part of a coherent plan. However, the findings of early studies invariably influenced the objectives of later ones; and each committed the next to examining essentially the same camping market. New Hampshire, being a small State with a well-developed park system and a strong tourist economy, provided an outstanding laboratory for this building-block type of research.

[6]See also: Reid, Leslie M.; OUTDOOR RECREATION PREFERENCES—A NATIONWIDE STUDY OF USER DESIRES, 1963, drawn in part from a survey of campers at Dolly Copp Campground in northern New Hampshire. Also see: THE NEW HAMPSHIRE STATE PARK STUDY, a survey report by the New Hampshire State Planning Project.

these variables, including many of the camper attributes, has some potential for manipulation by management.

Here are our findings:

- Direct increases in campground size (number of campsites), campground age (in years), and investment (in dollars), are accompanied by direct increases in visit length, visit frequency, and percentage of visitors who plan to return in the future.
- The presence of a swimming and boating attraction at or near the campground is associated with longer and more frequent visits, and more numerous plans to return.
- An increase in the number of activities engaged in at the campground is accompanied by a slight increase in camper satisfaction.
- An increase in campground crowding results in a drop in satisfaction to the level where campers stay only as long as planned.[7]
- The location of a campground is important to success. In a regional comparison, the less successful ventures were mostly in a region remote from major metropolitan centers, where lakes were scarce, competition (both public and private) was keen, and the camping season was shorter.
- An increase in the variety of past camping experience accompanies an increase in camping satisfaction, but it also accompanies a more critical reaction to campground crowding.[7]
- A preference for private campgrounds, as well as a lack of preference for public campgrounds, accompanies longer and more frequent visits, and a greater incidence of intentions to return.
- Highly mobile camping equipment was generally accompanied by shorter but more frequent visits; and the incidence of mobile equipment was 100 percent higher at private campgrounds than at public ones.
- Trip plans are apparently fairly flexible, judging from the increase in actual over planned visit lengths. A surprising

[7]LaPage, W. F. The Measurement and Significance of Recreational Experience. Unpublished Master's thesis, University of New Hampshire. 113 pp., 1962.

number of campers indicated that they had planned a 2- or 3-day visit and ended up staying a week or more.

- It is apparently impossible to identify "primary reasons for camping" such as economy, enjoyment of nature, or social contacts. Camping is a mixed bag of interests, including some apparently contradictory ones like "peace and quiet" along with the "opportunity to meet and visit with other campers".
- The incidence of past visits was almost invariably associated with longer current visits, and with a very high incidence of intentions to return. Past visits were also more common among private campground patrons.
- Campers who belonged to camping organizations were found to be twice as prevalent at private campgrounds as at public areas.
- The majority of successful campgrounds did not have camping owners whereas the majority of unsuccessful campgrounds were run by managers who were themselves campers.
- The majority of successful campgrounds had well-developed advance-reservation systems. And visits were longer at campgrounds with reservation systems than at those without them.
- The general finding that campground size accompanies success may indicate part-time management as well as fewer attractions and activities at many of the smaller enterprises.
- Successful campground owners were more than twice as likely to belong to a campground owner's association.

Questions of Motivation

It should be obvious from this list of major findings that most of our knowledge is correlative and not causative. For example, Are successful managers more likely to join an owner's association? Or are association members more likely to be successful? Or, more important, is there some unmeasured third factor that creates both success and membership? The same questions can be asked for almost every one of the findings listed. Lacking definite knowledge of which comes first—success or its attri-

butes—we can see that there is no magic formula for success in these findings. However, there are some important clues.

The content of practically every one of these relationships can be cataloged into one, two, and sometimes three broad classes of camper motivation. These are: (1) variety—an interest in many and varied recreational activities, and in the choice situations that they represent; (2) service—a desire for individual services, personal interest, convenience, and the ego satisfaction that these things represent; and (3) some less rational motivators such as habit and prejudice.

Picking the last category first, the evidence that campers (like non-campers) are creatures of habit is impressive. In our survey of private campground visitors, 93 percent of the campers who had been to the campground before predicted that they would come back; but only 59 percent of the first-time visitors expected to return. Among the 308 state park visitors surveyed in 1961, the desire to "seek a change in the daily routine" was a major camping motive only for the repeat visitors—involving 65 percent of them. And yet, in their quest for change, they ended up routinizing their leisure by returning again and again to the same campgrounds.

The power of habit is so strong that it prompted us to hypothesize the existence of a repeat-visit cycle, wherein more past visits create longer current visits, and longer current visits result in more future visits. In our private campground survey, only 37 percent of the first-time visitors to a campground stayed for 4 days or more. Sixty-two percent of the campers who were on their second visit stayed for at least 4 days. With 3 past visits, the percentage of 4-day stays increased to 69 percent; and after 4 or more past visits, it increased to 73 percent. Among all classes of visitors, the longer the visit, the greater the percentage of expected returns. For first-time visitors on a 1-day visit, 38 percent predicted that they would return; on 2-day visits, 52 percent; 3-day visits, 65 percent; 4- to 10-day visits, 71 percent; and 11 or more days, 79 percent.[8]

[8]The Private Campground Visitor. An unpublished manuscript in the files of the Northeastern Forest Experiment Station. FS-NE-1901, 1965.

The assumption is that if you can just get the camper onto this cycle of more visits and longer visits, he will be trapped there, a victim of his own habit pattern. There is probably a strong element of truth in this; but there are, of course, limits. Visits can become no longer than the amount of available vacation time; and eventually even the most pleasurable experiences can become monotonous. However, these limits can undoubtedly be extended by imaginative management that is attuned to minimizing monotony through providing for new experiences and new developments in and around the campground.

Incentives

How do you get campers onto this lucrative cycle? More specifically, How do you convince the first-time visitor to stay longer than he had originally planned? And how do you get all visitors to come back for a future visit?

Obviously, giving them a first-rate camping experience has something to do with it. Just as obviously, your competition will be attempting to do the same. So something more is needed—incentives. Two possibilities come to mind; and with a little reflection, most managers could develop others keyed to their own individual operating styles. One possibility: A first-time visitor, upon his arrival at the campground, could be given a certificate entitling him to 1 day's free camping for each 2 days of paid camping. This is not price-cutting, or attempting to sell 3 days of services for the price of two. The objective is simply to get the camper to stay longer, so that he will be better able to appreciate all that your campground and its environs have to offer. Another possibility: established customers could be given a certificate, after a paid visit of 4 days or more, which would entitle them to half-price camping, on week-days only, during their next visit. In this case you would not only provide the economic incentive to return; you also would have created a tool for spreading busy-week-end traffic over the usually slack week-days.

We have tentatively labelled preference for, or prejudice against, private campgrounds as one of the less rational motives influencing camper visits simply because we have not yet identified any firm basis for preferences. This in no way diminishes their importance. If we look at the return-visit intentions of first-time visitors only, the impact of preferences is unmistakable. Return-visit intentions among campers who preferred public campgrounds were only 41 percent. When no preference exists —for either public or private campgrounds—the return-visit intentions increase to 59 percent. And, among those first-time visitors who prefer private developments, 72 percent say that they will come back. The length-of-visit pattern for these three groups is equally striking: 2, 3, and 5 days, on the average, for campers with a public-area preference, no preference, and a private-area preference, respectively.

Combatting entrenched prejudices and preferences is never easy. But it is a problem that has received a lot of attention in the marketing field, and many of the lessons of experience learned elsewhere may be applicable to campground management. Admittedly, in our survey, most of the campers having a preference for public areas were visiting a private campground for reasons of simple expediency. Very often they were awaiting a vacancy at some nearby public campground where they had originally intended to go.

Perhaps trying to capture these campers as permanent customers would be difficult. On the other hand, through no effort of your own, you would have solved the major tactical merchandising problem of getting the opposition to try your product. It's a little like the housewife who finds the grocer is out of Brand X, so she must try Brand Y or go without. In this case, your product need not necessarily be better, but it must be as good. Furthermore, the preference for public campgrounds is based, at least in part, on the generally lower fees encountered there. So the camper who is forced to try your campground may be quite receptive to the economic incentives mentioned in connection with habit and the repeat-visit cycle.

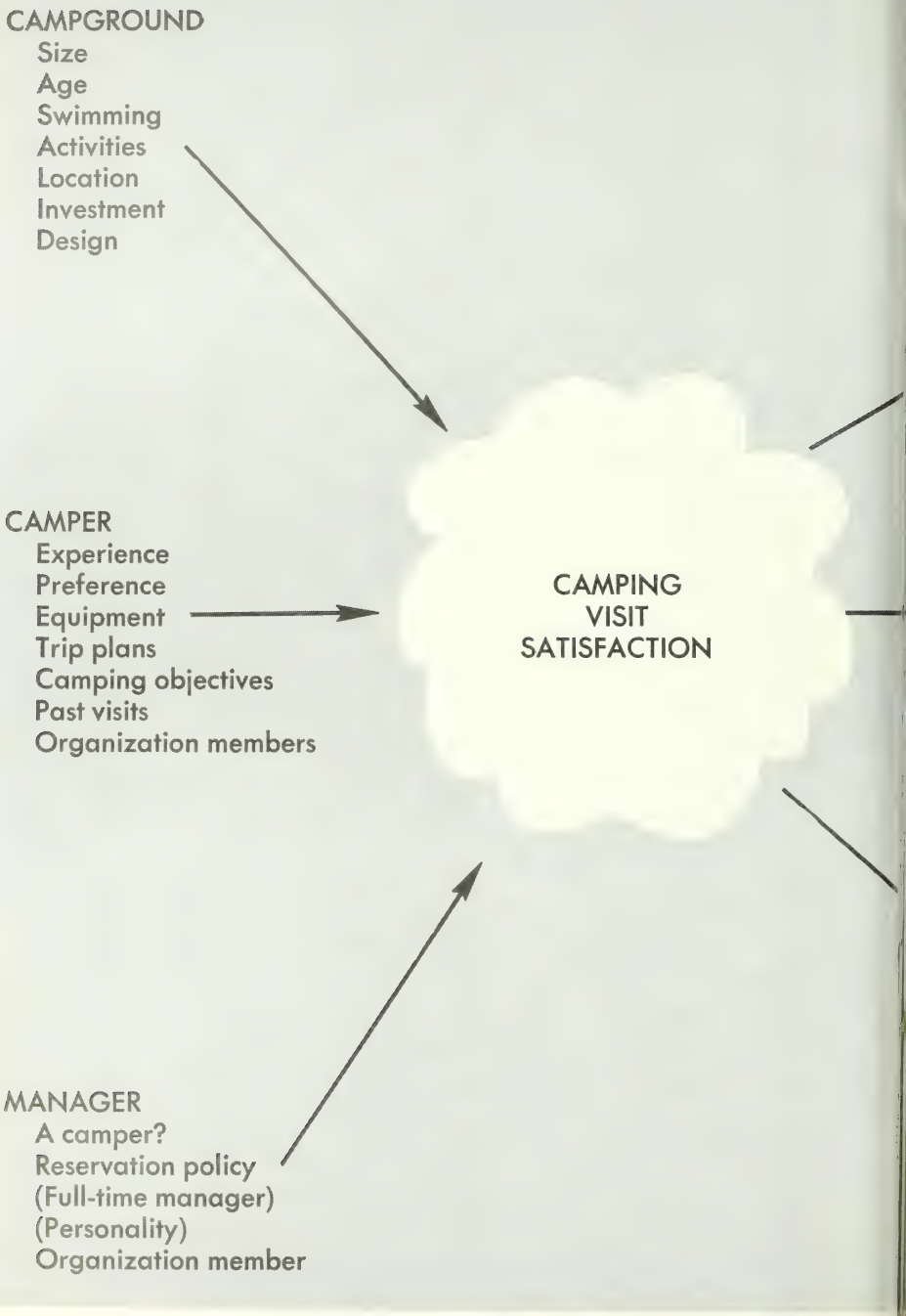
CAMPGROUND
Size
Age
Swimming
Activities
Location
Investment
Design
CAMPER
Experience
Preference
Equipment
Trip plans
Camping objectives
Past visits
Organization members
CAMPING
VISIT
SATISFACTION
MANAGER
A camper?
Reservation policy
(Full-time manager)
(Personality)
Organization member

Figure 1.—The successful campground model. The new materials—camper, campground, and managerial attributes—interact to produce camper satisfaction, resulting in longer visits, more frequent visits, and word-of-mouth advertising, all of which lead to success. All the relationships depicted here, except those connected with a variable enclosed in parentheses, have some basis in the research findings of one or more of the New Hampshire camper studies.

Finally, only 20 percent of the private campground visitors we surveyed were in this "campers without a campground" category. Another 38 percent expressed no firm preference in either direction, public or private. This is certainly a worthwhile size group of fence-sitters to aim a promotional campaign at. And you can be sure that whatever efforts you expend to win these campers over can never be as intensively matched by the efforts of public agencies.

Variety & Service

How to accomplish this dual goal of winning over the opposition and getting campers onto the repeat-visit cycle, takes us back into the other two categories of motivation—variety and service.

For a variety, a return to the grocer's shelf may be revealing. Today's supermarket is a model of merchandising efficiency that offers in a limited amount of floor space, an immense number of commodities; and for each commodity a large number of brands, sizes, and shapes. The many attractively displayed items are intended to be a substitute for the shopping list. The shelves are a smorgasbord of desirable items. If you have a brand-name preference, it is there. If you buy for status, you can pay more and get less. If you buy for economy, there are house-brands that sell for a few pennies less, but return a higher profit margin. And, if you have no preference at all, you can have the outright pleasure of selecting tuna fish in two grades, three colors, seven brands, and three sizes; or instant coffee in nine brands and three sizes. Shopping has become recreation. And to a large extent, recreation has become shopping. Not just shopping for the campgrounds, but shopping for what to do after you get there. Participation depends on the resources available.

One successful private campground operates on this same smorgasbord principle. The manager offers dozens of daytime and nighttime activities, sports, tours, and personalized instruction in water skiing, diving, tennis, and other sports. The owner's

guiding philosophy is that many campers today do not have a sharply developed idea of what the ingredients of a camping experience might be. By offering a variety of combinations, at a very reasonable $5 per family per day, he enables each camping family to construct its own personalized camping experience. Or, if they are bargain-conscious—and who isn't?—they can stay longer to take full advantage of everything that is offered. In addition to good business sense, the manager of this unique enterprise also has an outstanding physical resource, and a sincere personal interest in the comfort and enjoyment of every visitor.

This personal touch, to be effective, is not the veneer of the so-called red carpet treatment, nor is it a paternalistic hovering over each campsite. And it is not something that is very easily researched or scientifically described. Among the few campground managers who have it, there is outwardly little in common. Inwardly they seem to share a profound concern that each camper who passes through their gates will have discovered something of value. That something may be simply the smell of a campfire, or how to water ski, or it may be a more significant insight about oneself or one's family.

The personal touch to campground management has been carried to the extreme in another highly successful New England campground where the manager, who has a special facility for remembering names of his established customers, calls all of his campers—adults and children alike—by their first names. He also sends Christmas cards to all his camping families, and birthday cards to the children. This particular private campground is almost a private club.

These twin concepts of variety and service are getting out onto the thin edge of our research. Nevertheless, it may be worthwhile to simply list some of the ways in which variety and service can be incorporated into campground planning and management.

Service has been expressed in terms of such things as advance reservations, adequate (and appropriate) directional signs, trailer hook-ups, adequate roads within the campground, camp-

grounds located near urban areas and not too far off the beaten path, long seasons, 24-hour attendants, telephone availability, competence in first aid, children's activities, teen interests, baby sitting, bulletin boards, rental equipment, instructional services, well-spaced water taps and toilet facilities, night lights, camp stores, regular firewood deliveries and trash removal, pre-season notices of changes in rates and services, available shelters, assistance to new campers, hot water, showers, campground maps, area maps showing tour routes, arrangements for discount rates at nearby attractions, posted rules and regulations, liability insurance, and almost anything that reflects a concern for the camper's convenience, enjoyment, and protection.

Variety tends to invoke images of all kinds of activities, sports, games, movies, dances, and special events. But variety occurs elsewhere as well: in the design of campsites, roads and trails; in the distribution and density of campsites within the campground; in the effective use of shore lines, open, shaded areas, and edges; in the types of trees and shrubbery that are preserved and planted; in the types of campers attracted; in the personalities, interests, and abilities of campground employees; in the changes in program offerings from week to week and year to year; and even in the rate structure and discounts offered.

How you combine these elements of service and variety with your own specific goals and strategies in operating a camping enterprise is management. And this puts us even farther out on the fringe of our research findings because we know so little about the goals and strategies of campground owners. Some owners, because of other commitments, may want to develop the business slowly; others may want to build up attendance as fast as possible even at the expense of minimizing income during the early years; and still others may prefer to realize the maximum income on as few visitors as possible. Some owners may want to cater to a very specific clientele, while others may be more concerned with local area development and the filling of a general need for more campsites. And questions of economics are invariably tied to managerial strategy.

Some Economics of Visit Promotion

Up to this point, I have centered on the why and the how of promoting longer and more frequent visits, both directly through various incentives and indirectly through raising the level of camper satisfaction. And I have tried to stress the idea that both the direct and indirect approaches should be used together. To stress only the direct approach is foolishly deceitful, while emphasizing only the indirect means is foolishly naive. The question now is: Is is worth it? And I know of no empirical evidence to answer with. However, we can develop some concepts, which are theoretically sound—and you can test them.

"Is it worth the effort?" is really two questions in one: "Is there a potential for improvement?", and "Can enough improvement be realized to offset the costs of a promotional scheme?" Apparently there is a good potential for improvement in the rate of repeat visits. Only 30 percent of the private campground visitors surveyed had visited the campground previously. But as many as 72 percent (those having a preference for private campgrounds) expressed a desire to make a repeat visit. Even among the first-time visitors who claimed to prefer public areas, 41 percent expressed their hopes of returning. It seems highly likely that management incentives can pick up a portion of this gap between expectations and realizations.

The potential for extending visit lengths is less clear. Very few weekend campers could probably be induced to stay for an extra day. But among campers on a long trip, there is probably a large proportion whose plans are flexible enough so they could stay for an extra day or even an extra week. Our data do not indicate what proportion of campers have flexible plans. But we do know that more than 50 percent of the private campground visitors were on a trip of at least 2 weeks duration, while only 27 percent of them spent more than 1 week at a single campground. We also know that one out of every two private campground visitors spends at least 20 days camping, on three separate trips, each year. The potential for capturing extra days

and extra visits exists, at least for every other camper coming through the entrance gates.

Whether trying to capture some of this potential is worth the effort depends also upon a campground's present volume of business, management's goals for increasing the volume of business, and the campground's capacity to absorb new business.

There are different ways of looking at campground capacity. The first, and most obvious, is *design capacity*—the number of campsites multiplied by the length of the season. A 100-unit campground, in a resort area where business begins on Memorial Day and ends 100 days later on Labor Day, has a design capacity of 10,000 camper groups, or 50,000 camper-days (at 5 campers per group). A much more useful definition is that of *visit capacity,* which reduces design capacity by the average length of a visit to arrive at the maximum number of group-visits that can be accommodated per season. As the average length of camping visits increases, capacity decreases.

A 100-unit campground, with an average visit length of 3 days, will have a Memorial Day to Labor Day capacity of 3,300 camper groups. If the average visit increases to 4 days, capacity is reduced by 24 percent to 2,500 groups; at 5 days, 2,000 families can be accommodated; and at 6 days, capacity drops to 1,600. And, since the length of visit is significantly different between new visitors and repeaters, the proportion of repeat visitors, in the annual attendance, will have a distinct impact upon campground capacity, as the figures in table 4 indicate.

If management goals are to be realistic then, they must take into account this three-way relationship between repeat visits, average visit length, and campground capacity. Realism also rules out goals in the range of 80 to 100 percent occupancy simply because of weather and the weekly cycle of camping activity. Greater weekday attendance can be promoted, but it will never equal weekend attendance unless all the sites are leased on a monthly or seasonal basis, and no transients are allowed. Finally, realism involves an acceptance by the manager who has already achieved 50 percent of capacity-use that he will

Table 4.—*The effect of simultaneously raising the repeat-visit rate from 30 percent (actual past visits) to 70 percent (expressed intentions to return), and the average visit of new visitors from 2 days to 3.*

(Based on a 100-unit campground having a 100-day season)

Total attendance	Repeaters		Average visit	New visitors	Average visit	Weighted average visit	Visit capacity[1]	Use, as a percentage of capacity[2]
No.	*%*	*No.*	*Days*	*No.*	*Days*	*Days*	*No.*	*%*
3,300	70	2,300	4	1,000	3.00	3.75	2,670	124
2,500	60	1,500	4	1,000	2.75	3.50	2,860	88
2,000	50	1,000	4	1,000	2.50	3.25	3,100	65
1,700	40	700	4	1,000	2.25	3.00	3.300	52
1,400	30	400	4	1,000	2.00	2.57	3.900	36

[1]Visit capacity is determined by multiplying 100 campsites by 100 days, and dividing the product by the weighted average visit length.

[2]Determined by dividing total attendance by the appropriate visit capacity in the preceding column.

have fewer strategies open to him, and can expect smaller increments for his promotional dollar, unless he is willing to enlarge his campground. As table 4 indicates, it is impossible to increase repeat visits up to the rate at which people say they would like to return, and at the same time prompt new visitors to spend an average visit of 3 days instead of 2. As a matter of fact, it is probably impossible to come anywhere near approaching the 70 percent rate at which visitors say they would like to return.

Choose Your Goals

Obviously the major costs of operating a campground are the fixed ones, which go on unchanged, regardless of whether you entertain 50 or 500 campers. It is clearly better to have the campground occupied during slack periods even if the occupants may be paying reduced rates. Just as clearly, you don't want a lot of certificates for free or reduced-rate camping floating around which can be redeemed at any time. So, whatever promotional campaign is decided upon, it must be strategically designed to achieve only the goals you want it to. Given the situation of a 100-unit campground, operating at 36 percent capacity, with one-third of its visitors being repeaters (bottom line of table 4), four general strategies are apparent.

First, you could attempt to encourage repeaters to stay even longer than they already do. Their average visit could almost certainly be raised above 4 days since we know that their annual camping participation is five times greater than that. However, this carries with it the danger that the family that normally makes two 4-day visits per season to your campground might decide now to make only one 6-day visit. And perhaps one of those days will have been free as the incentive, resulting in a net loss of 3 days of paid camping from just that one family.

Second, a better strategy for repeat campers might be to hold visit lengths down and try to get the campers to come back more

often. For example, encourage the annual visitor to become a twice-annual visitor. This can be done either by discount rates for slack periods like fall weekends or summer weekdays, or by featuring a variety of special campground events during the season. A combination approach, featuring discount rates at times when special events occur in the surrounding community, is also feasible.

Third, you could try to promote longer visits by the first-time visitors. This seems to be a highly likely possibility, except for those on a weekend trip, by simply offering a third day free for every camper who registers for 2 days. Being a long-range strategy—extending the visit to get them onto the repeat visit cycle—this has some immediate costs. The costs are most evident for those new campers arriving on a Wednesday or Thursday, because their free day will then fall during the normally busy weekend. If capacity attendance on weekends is the rule at your campground, and there is no overflow capacity, this may not be an appropriate strategy unless you can modify it in some way.

Fourth, you could promote repeat visits by the new visitors. As already indicated, the best strategy for this may be to get them to stay longer on their first visit. On the other hand, not every new visitor has plans flexible enough to allow for an extension of the visit. Therefore, perhaps a combination of incentives that gives the new visitor his choice of an extra free day on his present visit, or on his next visit within the year, would provide the most comprehensive strategy for new visitors.

The number of possibilities for creating different types and combinations of incentives is limited only by the campground manager's imagination and his knowledge of his customers. In many respects, this face-to-face relationship of manager and customer is a far superior means of gaining understanding than the most carefully controlled scientific survey. Compared with interview techniques, your exposure to the camper is longer, more varied, less structured, less formal, and more relevant to the unique qualities of your own enterprise.

Something Besides Science

In this same vein, I would like to conclude this by voicing a warning about consumer research and "scientific" formulas for success. The dangers in this common idea, that success is like baking a cake, should be obvious at this point. The problem is nicely summarized by Theodore Levitt, in the *Harvard Business Review*.[9] Mr. Levitt's thesis is that management, in recent years, has failed to manage:

> It has been seduced by the self-confident and plausible claims of its researchers. But . . . management has been a compliant victim . . . because it does not consider what happens a seduction. Rather, it considers the whole affair highly scientific. And this has been a particularly congenial submission because management has always sought formulas and prescriptions for easier decision making. When easy formulas and scientific claims are accepted and employed without sufficient regard for the market conditions under which they will have to function, the senseless muddle which characterizes detergents, compact cars, and mentholated cigarettes is produced. No matter how many carefully controlled laboratory tests tell you that what is best for selling menthol cigarettes is green waterfalls bneath snow-capped mountains, the appropriate policy may be to avoid using these images if everybody else is using them. In marketing, sound strategy often consists not in doing a better job of what competitors are doing, but in doing what they are *not* doing.

The formula given in this paper—that success is a function of camper satisfaction—is obviously a do-it-yourself formula. Research can identify some of the things that produce satisfaction. Management can identify still others, and put them all together. But this is not enough in a highly competitive market.

You must also communicate with the camper, and convince him that you know what he wants, and that you can provide it. Gimmicks or incentives that will promote longer and more frequent visits are one way—possibly a very effective way—of communicating your awareness of camper interests. My suspicion that they may be very effective rests on the sure knowledge that they are not available to your major source of competition, the publicly owned and operated campgrounds. And this is not the

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[9]Levitt, Theodore. M-R SNAKE DANCE. Harvard Business Rev. 38(6): 76-84, 1960.

only weapon in the private campground operator's arsenal. You can also provide a level of personal service, advance reservations, and supervised activities that cannot be matched by public enterprise. And you can manipulate your fees to get a better distribution of attendance, whereas public campground fees are rigidly set.

In conclusion, each campground owner will have to write his own personal formula for success in the campground business. But the major ingredients are sure to involve promoting longer and more frequent visits through greater customer satisfaction.

■

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VACUUM PUMPING
increases sap yields from sugar maple trees

by Barton M. Blum and Melvin R. Koelling

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VACUUM PUMPING
increases sap yields from sugar maple trees

■

WHAT DOES THE VACUUM DO?

IN TWO RECENT studies of plastic tubing systems for collecting sugar maple sap, use of vacuum pumping increased the yield of sap. The evidence showed clearly that the vacuum actually draws extra sap from the tree.

Considerable work has been done in the past decade to develop plastic tubing systems for collecting maple sap. Though the labor-saving advantages and sanitary attributes of plastic tubing systems are well documented (*Willits 1965*), some aspects of installation and operation have received little attention. One is the use of vacuum pumps to aid the flow of sap through the plastic tubing.

Where vacuum pumps have been used in plastic tubing systems, taphole yields have been as much as three times larger

than those obtained by gravity flow, from both vented and unvented tubing systems (*Morrow 1963, Laing et. al. 1962a*). However, this increase in sap yield has been attributed to a reduction of sap loss by removing sap from the tubing quickly and preventing reabsorption into the tree at night, or by preventing vent loss due to obstruction of the tubing by ice and air locks (*Morrow 1963*). The potential for drawing additional sap out of the tree with vacuum was not fully explored in these studies.

The possibility that vacuum could play a more direct role in increasing sap yields came to the attention of researchers at the Northeastern Forest Experiment Station research unit in Burlington, Vermont, during an experiment designed to compare sap yields from vented and unvented gravity tubing systems. The unvented tubing system in this study, which was completed in 1966, yielded 43 percent more sap than the vented system (*Blum 1967*). More important, the results indicated that the magnitude of the differences was closely related to the amount of natural vacuum developed in the unvented system. This vacuum, caused by the movement of sap in the tubing, varied according to the volume of flow for a particular period, the vacuum-holding capacity of the tubing system, and the length and general slope or grade of the installation. Additional evidence of this relationship between vacuum and increased yield was obtained during the 1967 sap season.

These results posed two questions. Was the vacuum in the unvented system actually drawing the additional sap out of the tree, or did the 43-percent increase in yield reflect losses of some sort from the vented system? What would be the effect of sustained levels of vacuum applied to large-scale installations by means of a pump?

In the spring of 1967, a vacuum pump was installed at a sugarbush located in Underhill, Vermont, to investigate these questions. This work proceeded in two phases: an individual-tree study designed to determine if sap could be drawn out of a tree in sufficient quantities to account for large yield differences; and a large-scale study of the effects of sustained levels of vacuum on yields from a nearly commercial-size network of tubing.

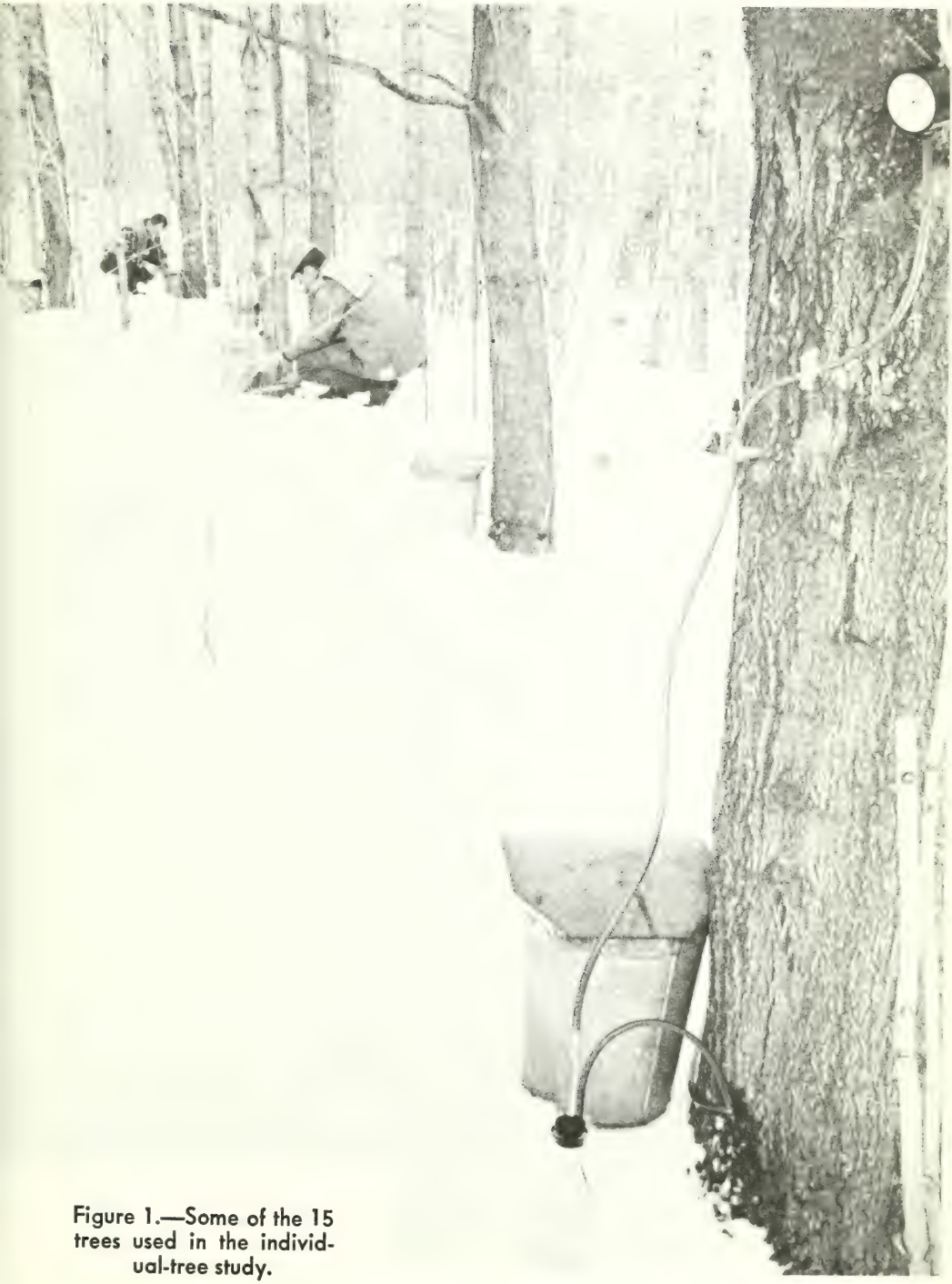

Figure 1.—Some of the 15 trees used in the individual-tree study.

INDIVIDUAL-TREE STUDY

This study was designed to determine if vacuum could increase yields over those obtained by gravity flow alone, by drawing additional sap out of the tree. We used 15 sugar maple trees in the 8- to 10-inch diameter class. These trees were tapped with two holes, paired 6 inches apart about 4½ feet from the ground, and drilled to a controlled 3-inch depth. One taphole in each pair was fitted with a tubing spile connected to a vacuum line; yields from these tapholes were collected by running the vacuum through a 500-milliliter side-arm distillation flask for each taphole. The other taphole in each pair was fitted with a similar tubing spile, and sap was collected by gravity flow through a short piece of tubing running into a covered bucket (figs. 1 and 2). Approximately 13 inches of mercury vacuum were applied to the vacuum tapholes while the pump was running.

Data were collected during four separate flow periods with a total pump time of 6 hours 50 minutes. The distillation flasks were emptied when necessary while the pump was running. Flow into the buckets was by gravity; and this was measured only for the same period when vacuum was applied to the vacuum tapholes.

The results indicate that direct application of vacuum at the level used in this study increased sap yields almost 700 percent. The average per-taphole yields were 2,239 milliliters for the vacuum system and 278 milliliters for gravity flow. These data were subjected to a "t" test for paired replicates, and differences were significant at the 0.01-percent level.

The magnitude of these differences may be misleading in one respect. Three of the four flow periods used in the study were weeping flows, purposely chosen to determine if the vacuum was actually drawing sap out of the trees. Viewed in this light, these yield differences bear no relationship to differences that might be achieved by applying vacuum under all flow conditions for an entire season. However, these differences do point to the fact that sap can be obtained in considerable quantity with vacuum when conditions are poor for natural flow (table 1).

Figure 2.—A typical taphole pair used in the individual-tree study. The vacuum taphole is on the left.

LARGE-SCALE STUDY

This study was a demonstration of how vacuum affects a network of tubing installed under conditions approaching those of a commercial operation. This network was designed to compare sap yields between a vented, aerial tubing system utilizing short drops from the spile (*Lamb 1966*), and a matching unvented aerial system with applied vacuum. Except that one system was unvented and was supplied with vacuum, the two systems were identical in all respects and collected sap from the same trees (fig. 3). The unvented system was also designed to bypass the pump so that comparisons between yields from the two could be made during periods when the vacuum pump was not in use.

One hundred seventy-one trees were used in this study, each tapped with two tapholes paired 6 inches apart and bored to a 3-inch depth exclusive of bark thickness. The vented system was randomly assigned to one member of each taphole pair, and the unvented vacuum system was assigned to the other. Taphole pairs were placed at 4½ feet from the ground unless this had to be altered to insure adequate slope in the lines.

Each of the two systems consisted of a network of 2,500 feet of 5/16-inch tubing, which collected sap from a maximum of

Table 1.—*Rate of sap-yield increase for direct vacuum application compared to gravity, for selected flows*

Date	General flow condition	Average daytime temperature	Pump time	Rate of yield increase per hour due to pumping	
		°F.	*Minutes*	*Milliliters*	*Percent*
March 22	Poor	34°F.	95	93.6	66
March 23	Poor	36°F.	90	269.4	1,478
March 25	Poor	37°F.	105	334.8	3,256
March 31	Fair	60°F.	240	205.8	9,492
April 8*	Good	40°F.	270	346.2	3,895

*Based on five replicates only, not used in primary analysis.

Figure 3.—The tubing networks in the large-scale study were identical in all respects except for method of venting.

30 tapholes before running into a ¾-inch mainline tubing. Three hundred feet of mainline tubing were used for each system. This mainline was unvented for the pumped system and vented for the gravity system. Average slope in the study area was approximately 12 percent. Care was taken to be sure that the paired installations carried sap efficiently when both were operating as gravity systems.

The mainline from the vented system ran directly into a series of 55-gallon collection drums. The mainline for the pumped system went first to the vacuum pump, and then to an additional series of collection drums (fig 4). Gravity sap yields collected in the drums before pumping were measured immediately before the pump was started, and sap yields were again measured as soon as the pump stopped.

During the period March 15 to April 21, the pump was operated on many weekdays when the temperature was above freezing, whether sap was running naturally or not. On weekends, the pump was operated on days when conditions appeared

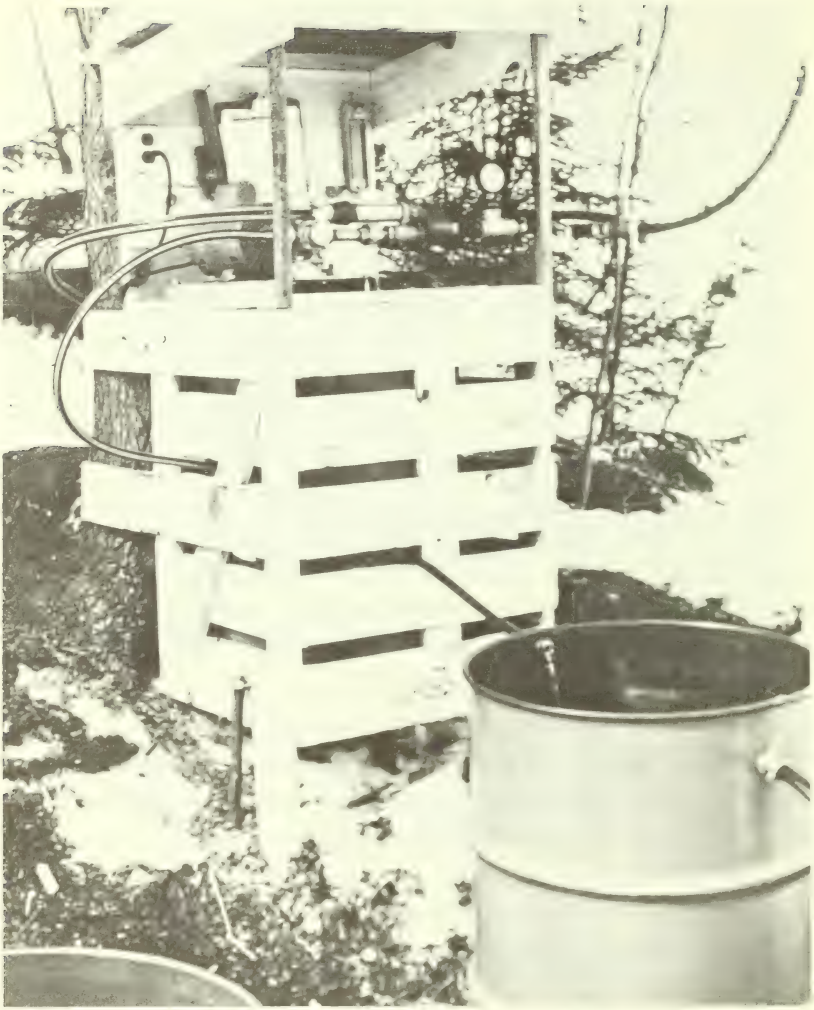

Figure 4.—The pump installation, showing the first drums in the collection series. Note yield from the pumped system entering barrel on the right.

to be adequate for a relatively good flow. The total operating time for the pump was 40.3 hours. When operating, the pump pulled approximately 15 to 18 inches of mercury vacuum. This vacuum was distributed evenly throughout the system with relatively little loss; it averaged about 13 inches of mercury at the tapholes.

Sap yields from the vacuum system averaged 385 percent greater than yields from the vented system for the 40.3-hour period the pump was operated. This large yield difference is primarily the result of yields obtained with the pump during periods when natural flow was very slow and yields from the vented system were negligible. On 6 of the 14 days when the pump operated, flow from the vented gravity system was less than 1 gallon per hour. On these same 6 days the flow from the pumped lines ranged from 9½ to 24 gallons per hour while the pump was operating (fig. 5). In fact some sap could be obtained from the pumped system on many days when the temperature went above freezing and the lines thawed, regardless of natural flow conditions. This sap represents a yield unobtainable with ordinary collection equipment.

No doubt the large percentage difference obtained with the pump reflects to a certain extent the relatively poor season in the spring of 1967. However, it serves to illustrate that vacuum pumping on tubing systems could gain enough additional sap in a poor season to be of great economic importance. Two producers using vacuum in New York and Vermont reported making up to 80 percent of their normal syrup crop in 1967, a season when most producers made much less.

In this study, the vacuum pump increased sap yields over those obtained from the gravity system during good flow conditions as well as poor flow conditions. The two best flows occurred on March 22 and April 8, when the 171 tapholes on the vented system were flowing at the rate of 8.0 and 9.1 gallons per hour. The flow rates on the pumped system for these dates were 11.2 and 33.2 gallons per hour (fig. 5).

As mentioned previously, sap was collected by gravity flow from both tubing systems when the vacuum pump was not running. These gravity yields provided a comparison between a network of vented and unvented tubing, including mainline. For the season as a whole, excluding the yields obtained when the pump was running, the 171 taps on the unvented system yielded 43 percent more sap than those from the vented system (table 2). This result parallels that obtained in Vermont in

1966. It is also in accord with the results of similar studies made by the Northeastern Forest Experiment Station and its Cooperators in Vermont, New Hampshire, and Massachusetts in 1967. This study thus provides further evidence of the greater yields from an unvented gravity system.

The combined vacuum and gravity yields from the pumped-unvented tubing system in this field study were 130 percent greater than the total seasonal yield from the vented gravity system. It is this total yield difference that the average maple producer is most interested in when considering the use of an unvented vacuum-pumped tubing system. The longer the pump is operated, of course, the greater the possibility of increasing this difference. In this study, for instance, the pump was not operated during one or two all-night weeping flows, when the pump might have increased yields considerably.

Table 2.—*Seasonal yields and yield differences for sap obtained by gravity in the vented tubing system and in the unvented system (excluding yields obtained while pump was operating)*[1]

Date of measurement[2]	Vented system	Unvented system	Yield difference
	Gallons	*Gallons*	*Gallons*
March 11	60.8	76.6	15.8
March 15	47.6	60.8	13.2
March 26	41.2	47.5	6.3
March 30	34.9	44.9	10.0
March 31	13.2	13.2	0
April 4	19.8	9.2	–10.6
April 5	55.5	105.7	50.2
April 9	11.9	26.4	14.5
April 14	46.2	76.6	30.4
April 16	22.5	18.5	– 4.0
April 27	15.9	15.9	0
April 28	61.0	118.9	57.9
Total	430.5	614.2	183.7

[1]Based on 171 tapholes.

[2]Actual flow of sap could have occurred at any time between date of measurement and previous measurement.

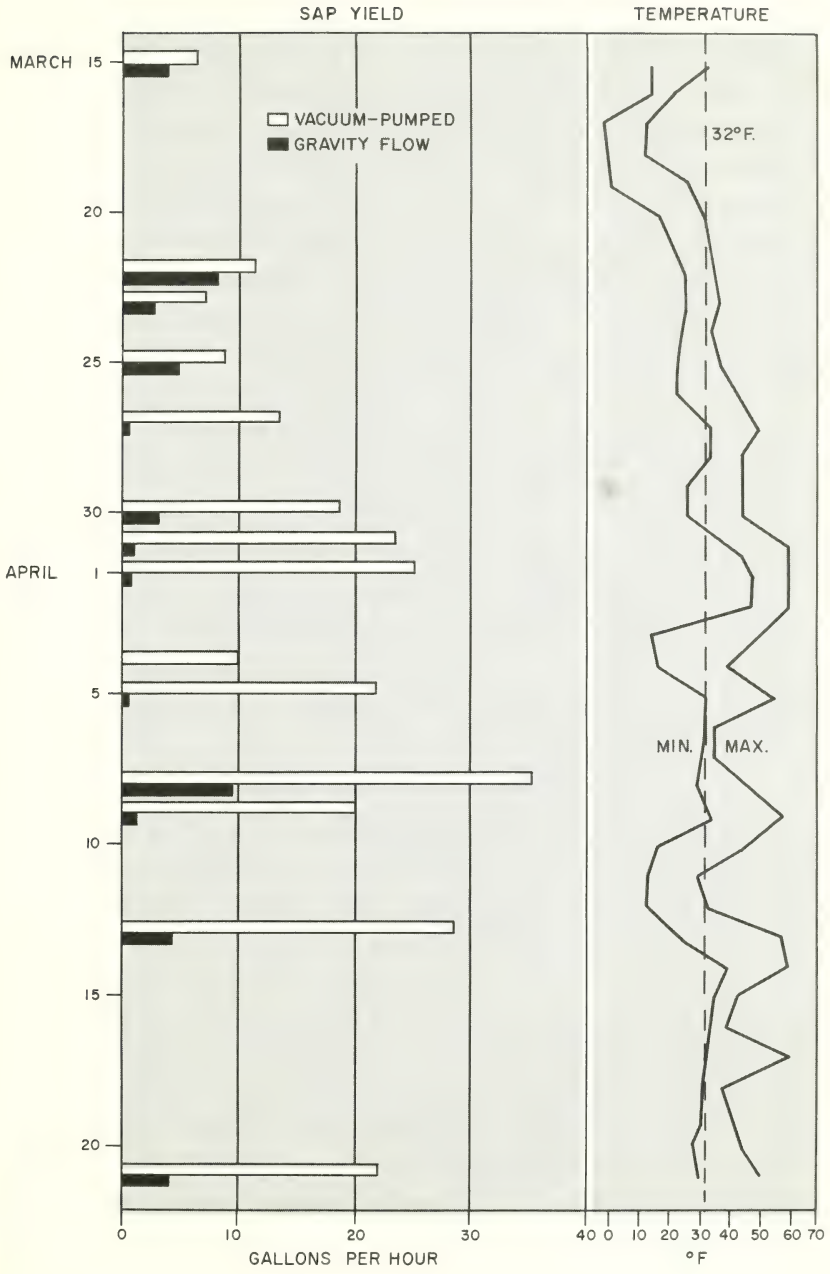

Figure 5.—Rates of flow for pumped and gravity systems, during periods of pump operation only. Daily maximum-minimum temperatures are shown at the top of the graph.

Two logical questions that arise when discussing the use of vacuum pumps with tubing are: (1) Does pumping shorten the sap season by "drying up" trees earlier? And (2) is there a difference in sap sweetness between that obtained by gravity flow and that obtained with a pump? Observations made in this study indicate that the answer to both questions is no, at least under the conditions that prevailed in 1967. Sweetness of the sap from both systems was measured periodically and was invariably the same; it compared favorably with the sweetness of sap collected from other studies on the same bush. Pumping yields remained high in comparison with gravity yields throughout the season. The last flow day when the pump was used was April 21, when flow from the gravity system was 3.9 gallons per hour and from the pumped system 21.1 gallons per hour (fig. 5). This sap had begun to turn buddy.[1]

[1]Buddy sap denotes a change in the chemical composition of the sap late in the season when the tree buds begin to swell. It has a strong odor and a disagreeable taste, and is not suitable for production of quality syrup.

DISCUSSION

The results of both the large-scale study and the individual-tree study provide evidence of increased yields due to the presence of vacuum in the taphole. The results of the individual-tree study indicate that the vacuum actually draws sap from the taphole.

These results have several important practical implications. Certainly any increase in seasonal sap yields of the magnitude found in the large-scale study is of economic importance to the maple producer. This is particularly true in light of the trend toward central evaporation plants where capital investment is high and large amounts of sap are needed during a relatively short season. Labor and equipment costs for a gallon of sap are also reduced considerably, since higher yields are obtained from a given outlay. Estimates made from our data indicate that on a 1,000-tap operation, the cost of the pump would almost be met from sap increases obtained the first year.

While it appears that vacuum is effective in increasing yield during good flow periods, the possibility of increasing yields during weeping flows may be more important—not only in contributing to the overall increase in seasonal sap production, but also by enabling a steadier supply of sap to reach the evaporator. Salvaging a poor or mediocre season through the use of vacuum pumping is an even more exciting possibility.

There are qualifications, however. Our results are limited to installations having the same vacuum levels we had. The pump used in our study was a commercially available jet type of pump operating on a venturi principle.

Even though the large-scale study was not replicated, conclusions drawn from the results should be valid when considered in the light of previous work. The relationship found between natural vacuum and yield (*Blum 1967*), and the yield increases due to pumping reported by Morrow (*1963*) and Laing et al. (*1962b*) all help to substantiate these results.

There are many unanswered questions. The effects of various levels of vacuum are unknown. The period of pump operation in our study was short, primarily because the sugarbush used was relatively inaccessible and transportation of fuel was a problem. The effects of longer pumping times on yield are unknown. And while the vacuum pump in a sense appears to have partially overcome temperature as a factor in volume yield, how temperature will in turn affect yield increases due to vacuum are unknown.

Based on our research results during the past 2 years, as well as the experience of others, enough evidence is available to justify the use of vacuum pumps in conjunction with tubing systems. We should caution that much remains to be learned about types of pumps and various levels of vacuum. The best approach would be to begin on a small scale and expand slowly as results warrant.

■

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Effect of vacuum pumping on LATERAL MOVEMENT OF SAP in the maple tree bole

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by Barton M. Blum
and Melvin R. Koelling

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

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BARTON M. BLUM, associate silviculturist, joined the Northeastern Forest Experiment Station in February 1957 shortly after earning his Master's degree in forestry from Yale University. He had earned his Bachelor's degree at Rutgers University in 1954, and served about a year with the U. S. Air Force in 1954-55. Mr. Blum has served at the Northeastern Station 3 years on forest surveys; 5 years on the silviculture project, then at Laconia, N. H.; and about 2 years on the maple sap production project at Burlington, Vermont.

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Effect of vacuum pumping on LATERAL MOVEMENT OF SAP in the maple tree bole

DOES THE SAP MOVE SIDEWAYS?

IN OUR EXPERIMENTS with tubing systems and vacuum pumping to collect sap from sugar maple trees, this question arose: Does the sap move sideways from one taphole to another? The answer, our studies show, is No.

Our recent studies of maple sap production have shown that unvented tubing collection systems yield more sap than vented tubing systems, and that these increases are related to natural vacuum that develops in the unvented systems (*Blum 1967*). Application of additional vacuum with a vacuum pump produced a further increase in sap yield (*Blum and Koelling 1968*).

In these studies we used a paired-taphole type of experimental design. Two tapholes were drilled 6 inches apart on the same tree; one taphole of each pair received one treatment (vacuum) while the other was a control (no vacuum).

This design is very efficient because comparisons of yield are all based on the same trees, thus eliminating differences between trees as a source of experimental error. The design assumes that yields from each of the two tapholes on a tree are independent of each other; that a treatment applied to one taphole does not affect the yield of the other taphole. With most treatments, this assumption seems valid. However, with treatments involving the application of vacuum to one of the two tapholes, it appeared possible that the vacuum at the one might draw sap away from the other. If this occurs, the implication that sap yields were increased by the application of vacuum may be erroneous.

The longitudinal arrangement of the xylem elements in maple wood and their natural role in conduction in a longitudinal direction make it unlikely that sap would be drawn in a transverse direction. For sap to move in this direction, it would have to find its way through a complex network of vessel, fiber, and ray elements by means of pits and through pit membranes. However, the possibility that transverse movement might occur could not be overlooked, and a series of experiments were conducted to investigate this possible source of error.

DYE EXPERIMENTS

First, dye substances were used in three experiments to trace the possible transverse movement of sap when vacuum was applied to one member of a taphole pair. Safranin, fast-green, and crystal-violet dyes, each dissolved in sap, were introduced into tapholes paired at various distances from vacuum tapholes. The dyed sap was supplied to the treated tapholes from a reservoir, and was present in the tapholes for the duration of the experiment. This dyed sap was absorbed into the tree during periods when normal sap flow was not occurring.

The vacuum pump supplied approximately 6 pounds per square inch of vacuum to the vacuum tapholes. Vacuum was applied for a total of about 14 hours, in periods ranging from

1½ to 4½ hours long. These periods occurred on ten separate days, and some natural sap flow occurred on each day.

Sap was collected from the vacuum tapholes in side-arm distillation flasks (fig. 1). For evidence of transverse movement of sap, we tried to detect dye color in this sap, and a pattern of dye streaks in the xylem tissue when the tree was dissected at the end of the experiments.

All tapholes used in this experiment were 7/16 inches in diameter and 3 inches deep, exclusive of bark. All tapholes were bored radially toward the tree center.

Experiment 1

Transverse movement of sap between tapholes 6 inches apart.

In this experiment, vacuum was applied to one member of a standard pair of tapholes spaced 6 inches apart, and dyed sap was placed on the other. The experiment was replicated twice on trees approximately 10 inches in diameter. Safranin dye was used in one replication, and crystal violet in the other.

We found no visible evidence that vacuum in one taphole in-

Figure 1.—Typical experimental installation, showing dye reservoir (upper left) and vacuum taphole with distillation flask for collecting sap.

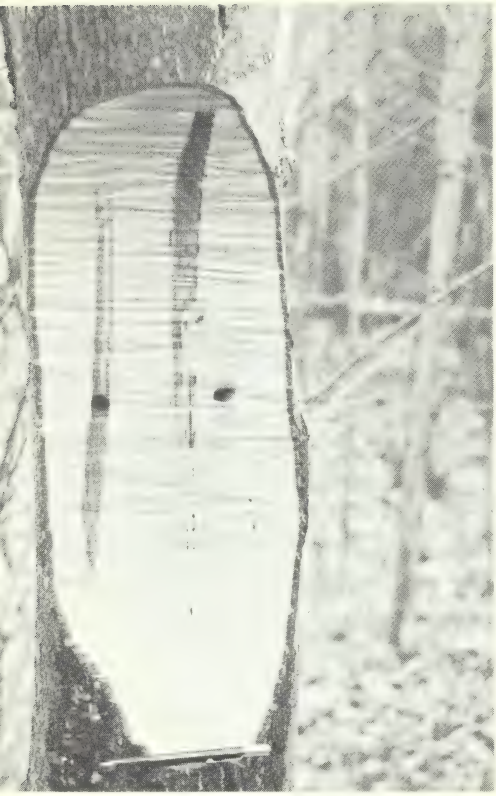

Figure 2.—Dissected tree bole, experiment 1. The dye streak above and below the taphole on the left shows no apparent movement of sap between it and the vacuum taphole on the right. Discolored area in the middle is the result of the old taphole above. These tapholes were 6 inches apart in the outside of tree; the tree is approximately 10 inches d.b.h.

fluenced the movement of sap in the other 6 inches away. No color was detected in the sap from the vacuum taphole, and the dye streaks above and below the dyed tapholes appeared to follow a symmetrical pattern (fig. 2).

Experiment 2

Transverse movement of sap between tapholes 1/4-inch and 1-inch apart.

In this experiment, a taphole was placed 1/4-inch to the left of a vacuum taphole, and another was placed 1-inch to the right of the same vacuum taphole. Safranin-dyed sap was placed in the left-hand taphole, and fast-green-dyed sap in the right-hand taphole.

Traces of safranin dye were detected in the sap from the vacuum taphole in this experiment, indicating some transverse movement of sap. On dissection, we found that the tapholes converged slightly; and the actual thickness of the xylem tissue through which movement took place was about 1/8 inch (fig. 3).

No fast-green dye was detected in the sap from the vacuum taphole. However, on dissection, the dye streak surrounding the taphole (1 inch away from the vacuum taphole) indicated that the vacuum apparently had an influence on sap movement (fig. 2). Dyed sap had moved transversely through the 1-inch segment of xylem tissue, but not in sufficient quantity to be detected in the sap from the vacuum taphole. In fact, the movement of dye appeared to stop just short of the vacuum taphole.

Experiment 3

Radial movement of sap between tapholes 1 inch apart.

Two tapholes were drilled directly opposite one another so that approximately 1 inch of xylem separated them in a radial direction. Crystal-violet dye dissolved in sap was used in one taphole and vacuum was applied to the other. No evidence of radial movement of sap was indicated from the dye streak, nor was dye detected in the sap extracted from the vacuum taphole (fig. 4).

In summary, we found in these experiments no visible evidence of transverse movement of dyed sap between tapholes paired 6 inches apart, when vacuum was applied to one member of the taphole pair. However, some transverse movement of sap due to vac-

Figure 3.—Experiment 2. Dye tapholes approximately 1/8 inch and 1 inch from middle vacuum taphole. Pointers indicate the outer limits of the dye streak around the right-hand taphole.

Figure 4.—Experiment 3. Dye streak indicates that radial movement of sap did not take place in the 1 inch of xylem tissue between the two tapholes.

uum was evident between tapholes very close together — through 1/8 inch of xylem tissue and through nearly 1 inch of xylem tissue. There was no evidence that vacuum influenced the radial movement of sap through xylem tissue 1 inch thick or thicker.

PRESSURE EXPERIMENTS

Still the possibility remained that sap might move transversely through 6 inches of xylem tissue while the dye substances could not. So we tried a different approach, using pressure dissipation as an indication of sap movement.

When conditions for sap flow are present, considerable sap pressure is developed in the tree bole. This pressure is relieved by drilling a taphole, and the pressure immediately above and below a flowing taphole is lower than that elsewhere (*Jones et al. 1903*). It seems logical that, if vacuum or negative pressure were drawing sap from the tree in a horizontal plane, this would be accompanied by reduced pressure in a horizontal plane.

Two comparable sugar maples about 20 inches in diameter were chosen and tapped at the same height on their south, east, and north faces. Pressure gages calibrated in pounds per square inch were threaded tightly into each taphole so no leaking occurred.

Six inches to the left of the pressure gage on the south face an additional taphole was bored on each tree. On one tree, the

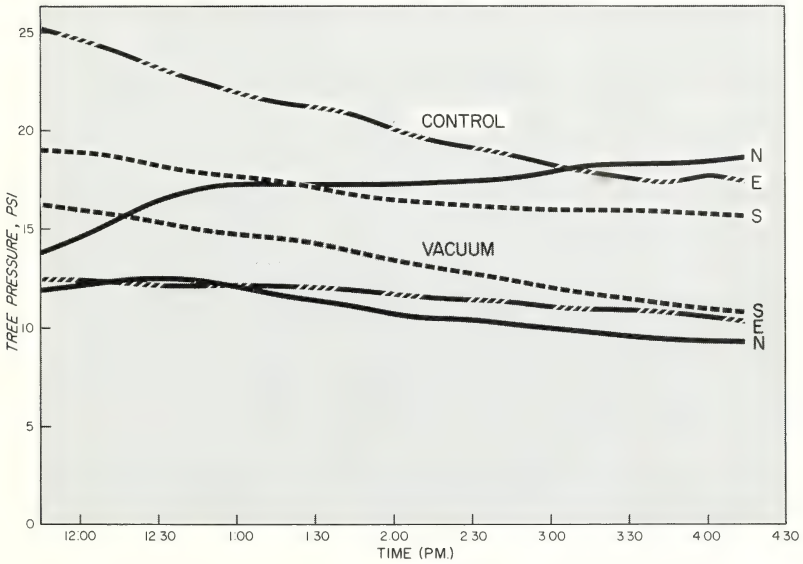

Figure 5.—Pressure patterns for the north, east, and south faces of the two study trees. The control tree was tapped 6 inches away from the south pressure gage, and sap was allowed to flow by gravity. The vacuum tree was tapped 6 inches from the south pressure gage, and sap was extracted by vacuum.

control, this taphole was allowed to flow by gravity. On the other tree, a tubing spile with attached vacuum line was placed in this taphole, and 13 inches of mercury vacuum was applied. Yields from the vacuum taphole and the gravity taphole were measured periodically.

This experiment was run on three separate flow days. Tree pressures, which were recorded every 15 minutes, were generally

highest in the morning and gradually diminished throughout the day on both trees.

Reduced pressure in a horizontal plane from the vacuum taphole would have been indicated on the south-face pressure gage by a lower relative reading than would be expected from the normal pattern of pressure observed on the three faces of the control tree.

No such lower reading was observed. And no distinct pattern in tree pressure could be established among the faces on either of the trees (or between the south faces of both trees) that could be attributed logically to the presence of vacuum in the taphole on the vacuum tree (fig. 5). Nor did the pressure of the south taphole on the vacuum tree dissipate more rapidly during the day than the pressure of the same taphole on the control tree (table 1).

Our conclusion that vacuum did not appreciably affect the positive pressure in a taphole 6 inches away is somewhat in accord with that reached by Jones et. al. (*1903*), who stated that lateral transfer of positive pressure in maple tissue may not extend over 1/8 inch.

Jones also stated that positive pressure is transmitted vertically. In similar exploratory work, we found that negative pressure is also transmitted vertically at least 1 foot in the tree bole.

Table 1.—*Rates of sap yield and pressure dissipation per hour from a taphole pair on the south faces of control and vacuum trees*

Date	Sap yield		Pressure dissipation[1]	
	Control tree	Vacuum tree	Control tree	Vacuum tree
	Milliliters	*Milliliters*	*PSI*	*PSI*
April 9	(*)	(*)	1.5	1.5
April 10	428.00	776.00	.7	1.3
April 13	695.79	1,035.79	.7	1.2

[1]Tree pressure dissipates slowly after an initial rapid rise on warm days that are preceded by an extended cold period.

*Not measured.

However, after numerous attempts, we were unable to detect a lateral transfer of negative pressure between tapholes paired 6 inches apart.

CONCLUSION

Neither dye nor pressure experiments gave any indication that transverse movement of sap occurs between tapholes placed at least 6 inches apart on the tree bole, when one of the two tapholes is supplied with a vacuum source as high as 6 pounds per square inch. The results also indicate that vacuum has little influence on the radial movement of sap between tapholes placed opposite one another on the same horizontal plane, separated by as little as 1 inch of xylem.

On the basis of this evidence, it appears that the presence of vacuum in one member of a taphole pair will not affect the yield of the other taphole.

■

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VARIATION of sugar maple sap yield and its influence on EXPERIMENTAL DESIGN

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by Barton M. Blum and Carter B. Gibbs

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VARIATION of sugar maple sap yield and its influence on EXPERIMENTAL DESIGN

A PROBLEM OF EXPERIMENTAL DESIGN

ANYONE who has ever emptied sap buckets in a sugar maple grove knows that sap yields vary greatly among individual trees. Some trees yield a lot of sap, others very little. When the Northeastern Forest Experiment Station began its research on maple sap production in Vermont a few years ago, we found that this variation in sap yield posed a problem for us in designing our experiments. It precluded the use of random sampling; so we had to find some other basis.

The variation in sap yield may be attributed to many factors. Tree and crown characteristics, stand and site characteristics, taphole dimensions, and location, and the genetic potential of the tree apparently all contribute (*Robbins 1965; Morrow 1955; Jones et al. 1903*).

Statistical testing techniques provide a means of evaluating this sort of variation. If variation between trees that received different treatments is large in relation to the natural variation among individual trees, we can attribute the observed differences to the treatments. However, if natural variation among trees is very large—as it appears to be with maple sap yield—then either the number of trees sampled must be very large or the differences resulting from the treatments must be very large to attain statistical significance with simple randomized experiments.

More efficient experimental designs provide some means of grouping experimental plots into blocks or pairs so as to minimize the natural variation among the members of the block or pair. For example, two trees known to have about equal natural sap yields might be paired; or two tapholes on the same tree might be paired and then each taphole could be considered an independent plot. In both of these examples, the natural sap yields of the two experimental units are about equal, and differences in yield that result after random assignment of a treatment to one member of the pair can be attributed to the treatment with considerable confidence. In making statistical tests, a relatively smaller number of samples is needed for these designs as opposed to completely random designs for detecting a given size difference in yield.

Both of the grouping techniques mentioned above have limitations in maple sap production research. The use of several tapholes on the same tree raises the theoretical objection that these tapholes may not yield independently: the application of a treatment to one taphole might also affect the yield of the other. To avoid this objection, the two tapholes are spaced as far apart as possible but still are kept on the same side of the tree so that exposure, temperature, etc., will be similar. This effectively limits to two the number of tapholes that may be used on all except very large trees. Thus experiments are limited to those involving only two treatments—or one treatment and a control. Another question is whether or not paired tapholes on the same tree can be expected to yield like amounts of sap.

The other technique—grouping trees with similar sap yields—requires that records of the past yields of individual trees be available for making the groupings. Further, this technique assumes that trees grouped on the basis of past yield will continue to yield in the same relative proportions in subsequent years.

When sap production research was begun by the Northeastern Forest Experiment Station in Burlington, Vermont, in 1964, it became apparent that more quantified information on sap yield variation among individual trees and among years was needed to facilitate the designing of efficient experiments. One of the first projects undertaken was to record seasonal sap yields on approximately 140 individual trees on a sugarbush near Jericho, Vermont. Yields were measured in the sap seasons of 1965, 1966, and 1967. Data presented in this report are based for the most part on a random sample drawn from these trees. All sample trees were tapped with two tapholes bored to a uniform depth.

RESULTS

The yield of 24 randomly selected trees was first analyzed to quantify the variation in sap yield. Average taphole yields for this sample of trees ranged from 14 to 80 liters in 1965, 6 to 106 liters in 1966, and 2 to 77 liters in 1967. The coefficients of variation were 42, 52, and 59 percent for 1965, 1966, and 1967 respectively.

Data from these same trees were analyzed to determine the number of sample trees that would be required to detect an average difference of 5 liters per tree in a hypothetical experiment involving two treatments with trees assigned to treatment completely at random.[1]

Using data from 1967—the year with the largest coefficient of variation—we found that approximately 257 sample trees would be required to obtain statistical significance. It would usually be impossible to conduct such a large experiment.

[1]Computations were based on a test of significance at the 5 percent level, assuming an acceptable β error of 10 percent.

Grouping of Trees On Basis of Previous Yield

To determine whether the relative yield of a tree is consistent from year to year, the 24 trees used in the previous analyses were ranked according to their sap yields the first year of measurement—1965. These same trees were again ranked on the basis of yields in 1966 and 1967. The majority of the trees changed their ranking by 3 or 4 places compared to their 1965 rankings, and a few changed as much as 11 places (table 1). However, ranking in 1965 was significantly correlated (at the 99-percent level) with that in 1966 and 1967 (1965-66, $r_k = 0.70$; 1965-67, $r_k = 0.68$)[2], indicating that grouping on

Table 1.—*Trees ranked according to yield obtained in 1965 (base), 1966, and 1967*

Tree No.	Rank		
	1965	1966	1967
7	1	1	1
81	2	6	2
15	3	4	6
86	4	2	4
51	5	3	5
71	6	5	7
63	7	10	12
16	8	11	8
76	9	14	3
65	10	13	17
45	11	7	11
78	12	12	19
66	13	16	10
18	14	18	21
40	15	9	13
35	16	19	18
33	17	17	14
80	18	20	15
21	19	15	16
55	20	8	9
24	21	22	22
60	22	23	23
69	23	21	20
48	24	24	24

the basis of previous yield is a valid procedure. This result is similar to that reported by Morrow (*1952*), and is essentially similar to rankings shown by Taylor (*1956*) for sap sugar concentration.

Total sap yield for the same sample of trees in 1965 was also significantly correlated (at the 99-percent level) with yields from 1966 and 1967 (1965-66, $r = .84$; 1965-67, $r = 0.84$)[3]. This is another indication that variation in yield among trees in a stand is consistent from year to year.

To carry this a step further, we expanded the sample to 30 trees, which were then paired on the basis of their 1965 yields. Thirty trees were used in the sample so that 15 pairs of trees could be used in the analysis, comparable to the number of pairs used in many of our other experiments. Differences in mean yield for these pairs obtained in 1965, 1966, and 1967 were then tested for significance, using the t-test for paired replicates. No significant differences were found among the mean yields for any of the pairings.

The trees were then paired on the basis of their average yields for 1965 and 1966, and differences between this average and the mean yields obtained in 1967 were tested; they were also non-significant. These t-tests indicate that trees paired on the basis of equal yield can be expected to yield equally in subsequent seasons.

To evaluate the gain in efficiency that might result from grouping trees on the basis of their previous yields, we calculated the number of samples that would be required in a hypothetical experiment using the same data and assumptions previously used for the completely random experiment. We found that only 54 pairs (108 trees) would be required for the pairing design, as opposed to 257 trees for the random design. Similar calculations using other study assumptions revealed that the completely random design generally requires about 2½ times as many trees as the paired design.

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[2] r_k = Kendall's rank correlation coefficient.

[3] r = Standard correlation coefficient.

Grouping of Tapholes On Individual Trees

Many of the initial experiments undertaken by the Northeastern Forest Experiment Station in tubing use and spile design were based on tapholes paired 6 inches apart on the tree bole. The assumption was that these tapholes would yield comparable amounts of sap. This assumption was tested in 1967, using seasonal sap yields from 15 taphole pairs on a sugarbush in Essex Center, Vermont. Differences in the mean yields from the 15 pairs were non-significant, with a calculated "t" of 1.0. The assumption that tapholes paired close to one another would yield comparable amounts of sap was therefore valid, at least in this particular case; and there is no reason to believe the validity of the assumption would differ with a different sample.

Sap yields from tapholes located on the same tree have been observed by many to vary according to location on the tree, in regard to compass direction, although most observers have noted that this variation is not very great (*Jones et al. 1903, Robbins 1965, and others*). Since this variation is primarily the result of differences in temperature regimes at different locations on the tree bole, it would be expected to be greatest between tapholes located opposite one another on the north- and south-facing sides of the tree.

To investigate the feasibility of using paired tapholes on trees regardless of proximity to one another, we tapped 24 trees in 1966 with two tapholes. One taphole faced south, the other north. Taphole dimensions were strictly controlled, and the tapholes were located on the same horizontal plane. Differences in mean yield from the paired tapholes were tested with a t-test for paired replicates, as before. Differences in the mean yield for the 24 pairs were non-significant, with a calculated "t" of 1.17. It would appear valid then, to pair tapholes on the same tree, regardless of location in regard to compass direction, provided external sources of variation, such as the shading of one member of the pair by an understory tree, are not present. This would also allow use of three or more tapholes on a tree in studies involving more than two treatments.

These results are in accord with our previous unpublished findings on the effects of compass direction on sap yield, and are in accord with data reported by Jones et al. (*1903*), Robbins (*1965*), and others.

Another question about the use of paired tapholes on the same tree is whether the two tapholes are truly independent. Independence of yield when a vacuum was applied to one member of the taphole pair was tested in 1967. No evidence of horizontal movement of sap was found between tapholes 6 inches apart under these conditions (*Blum and Koelling 1968*). In view of these results, and because sap movement and wood structure are known to be oriented vertically rather than horizontally, the assumption of independence appears to be valid.

SUMMARY AND CONCLUSION

Measurements of seasonal sap yields in 1965, 1966, and 1967 show that variation in sap yields among individual trees is very large. The magnitude of this variation precludes the use of simple random sampling as a basis for experimental design.

Variation can be reduced greatly by grouping trees on the basis of previous sap yields. This requires spending at least one season determining the yield potential of the trees in question before experiments can begin. However, it provides a much more efficient statistical test and enables detection of smaller treatment differences or the use of fewer samples than simple random designs.

A similar result can also be obtained by grouping or pairing individual tapholes on a single tree. This eliminates the necessity for measuring sap yields before beginning studies.

Which of the two grouping techniques will be best depends upon the requirements of the particular experiment. If there are only two or three different treatments and they can be applied to individual tapholes (for example: comparisons of spile

design or tubing vents), the use of grouped tapholes on each tree will probably be most satisfactory. Where there are numerous treatments to be compared, or where the treatments must be applied to entire trees (for example, fertilizer experiments), the use of trees grouped on the basis of previous yields will probably be necessary.

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THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

Depth, weight, and water storage of the FOREST FLOOR in white pine stands in Massachusetts

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by Donald L. Mader and Howard W. Lull

U. S. FOREST SERVICE RESEARCH PAPER NE-109
1968

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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The Authors

DONALD L. MADER, a forest soil scientist, received his Bachelor's degree from the New York State College of Forestry at Syracuse University, and his Master's and Ph.D. degrees in soil science from the University of Wisconsin. Since 1956 he has been on the faculty of the Department of Forestry and Wildlife Management, College of Agriculture, University of Massachusetts, in Amherst. He is responsible for teaching and research in the fields of forest soils and ecology. His primary research interests are soil-site studies and watershed management.

HOWARD W. LULL, a forester-hydrologist, received his Bachelor's degree from North Carolina State College, his Master's degree from Yale University, and a Ph.D. from the University of Maryland. He joined the U. S. Forest Service in 1946 after previous employment with the Tennessee Valley Authority and the U. S. Soil Conservation Service. He has worked at the Forest Service's Intermountain and Southern Forest Experiment Stations and is now a project leader in watershed-management research at the Northeastern Forest Experiment Station, Upper Darby, Pa.

FOR MOST forest types we know very little about the forest floor and how well it stores water. This is true for the white pine type in the Northeast, so we undertook a study to gather information about the depth and weight of the forest floor as well as the content of organic matter in the floor under white pine (*Pinus strobus, L.*) stands. Other aims were to find out why the forest floor accumulates more in some areas than in others and how the water-storage capacity of the forest floor can influence floods.

[1]A contribution of the Department of Forestry and Wildlife Management, Experiment Station, College of Agriculture, University of Massachusetts, in cooperation with the Northeastern Forest Experiment Station, Forest Service, U. S. Department of Agriculture. Support for this study came from cooperative aid funds of the U. S. Forest Service, Regional Research Project NE-27, and Massachusetts Experiment Station Project Hatch 78.

In our study we took two sets of measurements: (1) the physical nature of the forest floor, and (2) the moisture content and drying rate of the forest floor.

First we measured the depths of forest floors under white pine stands in Massachusetts, and weighed their organic matter content. We took samples from 65 $\frac{1}{10}$-acre plots (fig. 1).

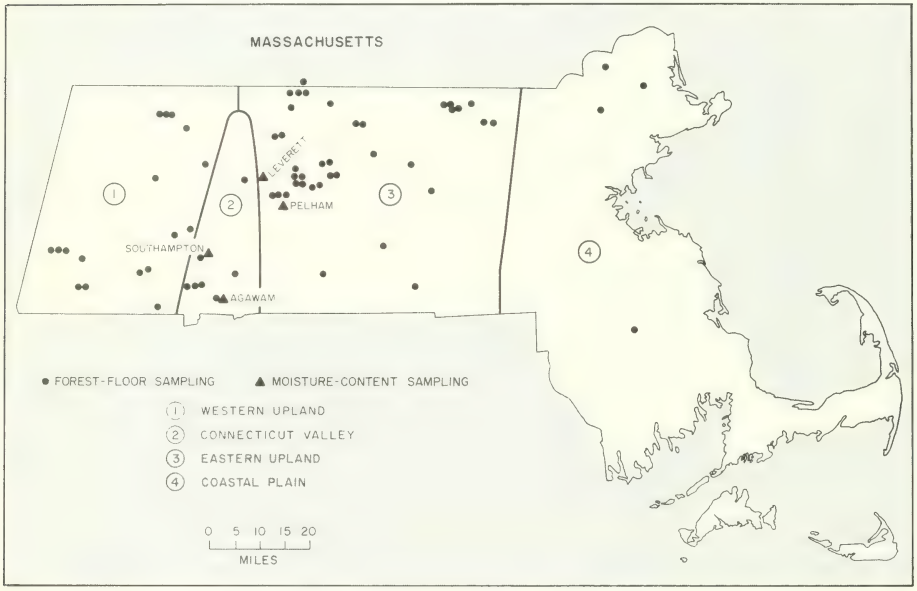


Figure 1.—Location of sampling plots and geographic provinces.

Sampling was done in summer 1962 and 1963. At each plot two 1-square-foot areas of the forest floor were sampled.[2] Samples were separated by layers on the basis of these generally accepted divisions: L for undecomposed needles and twigs, F for partially decomposed organic matter but recognizable as to origin, and H for humified, well-decomposed organic matter. Then the samples were air-dried and weighed. Oven-dry weight

[2]The term forest floor as used here includes the superficial organic layers lying above the mineral soil.

(at 103°C.) and organic-matter content (loss on ignition in a muffle furnace at 600-700°C.) were determined on subsamples.

No recent cutting, grazing, or fire was evident on any of the 65 plots. Stands ranged in age from 34 to 96 years, in basal area from 92 to 309 square feet, and in site index (height of dominants and co-dominants at 50 years) from 47 to 80 feet. By major geographic provinces, 17 of the plots were located in the Western Upland, 7 in the Connecticut Valley, 37 in the Eastern Upland, and 4 in the Coastal Plain (fig. 1). Plot elevations ranged from 25 to 1,440 feet. Twenty-seven plots were located on deep sands and gravels, 10 on aeolian or water-laid mantle over coarse subsoil, 4 on coarse-textured tills generally with no pan, 23 on fine-textured tills generally with a pan, and 1 on peat. As to drainage, 3 plots were very poorly or poorly drained, 5 somewhat poorly drained, 9 moderately well-drained, 33 well-drained and somewhat excessively drained, and 15 excessively drained. The characteristics of each plot are given in table 1 (Appendix).

In the second part of the study, moisture contents and drying rates of the forest floor layers were measured at four areas (fig. 1). Two areas in central Massachusetts were sampled at intervals of 1 to 3 weeks from April to November 1963. One of these, in the town of Leverett, consisted of a dense stand approximately 65 years old, 55 feet in height, and 181 square feet per acre in basal area. The other, 5 miles distant, in the town of Pelham, was a plantation about 46 years old, 54 feet in height, and 203 square feet per acre in basal area. By means of a small wooden frame, four 6-inch sections of the forest floor were removed at each sampling. Separated layers of each sample were placed in plastic bags to prevent moisture loss, then were taken to the laboratory where they were weighed, oven-dried, and analyzed for moisture content and organic matter.

In April and May 1964, we took weekly samples on these two areas and on two additional areas in southwestern Massachusetts, one in the town of Southampton and the other 10 miles away in the town of Agawam. The stand in Southampton was about 72 years old, 71 feet in height, and 256 square feet per

acre in basal area; the one in Agawam was about 40 years in age, 48 feet in height, and 170 feet per acre in basal area. An improved sampling frame with heavy vertical wires attached was used (fig. 2). The wires stabilized both the wooden frame and the organic materials when the layers were cut and removed inside the frame.

We estimated maximum storage capacities from representative recurring maxima and minima on the four study areas; then we tabulated the data in moisture percentage by weight and by volume for the L, F, and H layers. The four lowest and highest values were used, except in three cases where the fourth value was inconsistent and therefore was not included. Moisture contents by volume were based on the measured humus thickness for each sampling point.

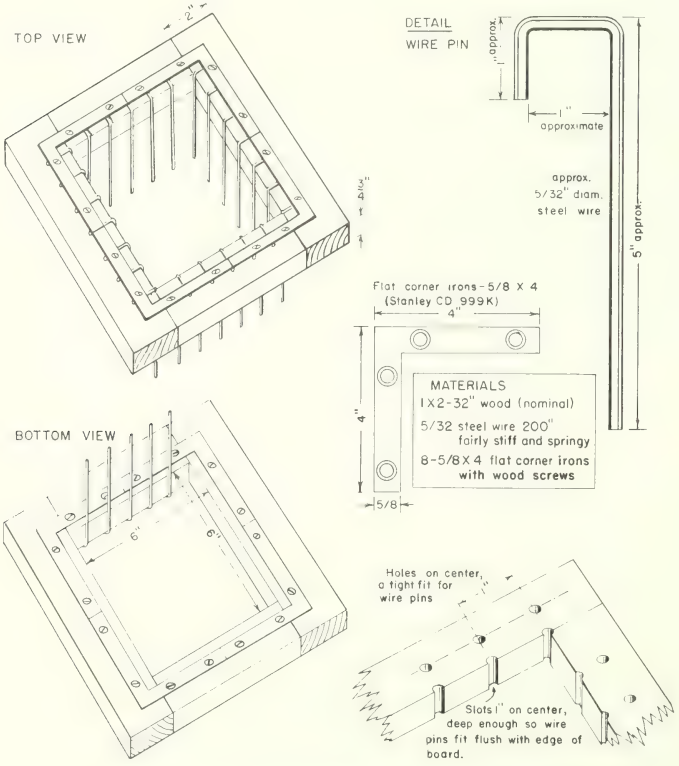


Figure 2.—Frame for sampling forest floor.

Weights of the forest-floor samples as well as the contents of organic matter and moisture of the four areas were analyzed for sampling errors. Standard errors of 4-sample means for the entire forest floor were about 5,000 pounds per acre—equivalent to confidence limits (at the 95-percent level) of about 30 percent of the mean. Mean moisture contents in inches of water, based on 4 samples, had confidence limits of about 30 to 80 percent of the mean. For extended discussion of sampling errors by locations and layers see the Appendix.

In this paper, we give first the mean accumulations of all plots in inches of thickness and weight by layers and by total amounts. Next we analyze differences in accumulations by geographic provinces and by soil-parent materials to show the influence of regional patterns of climate and soil. Then we give bulk densities of the forest-floor layers followed by: correlations and regressions of thickness of the various layers to their weights, along with correlations of forest-floor weights to organic-content weights and correlations of thickness between layers and weights between layers; simple and multiple correlations and regressions of forest floor and organic-matter accumulations on age, basal area, site index, elevation, and soil-drainage class for the 65 stands. Finally, we estimate moisture storage of the forest floor and daily drying rates and discuss the possible effects of these factors on floods.

Mean Accumulation for All Plots

Forest floors averaged 2.5 inches deep and 20 tons per acre oven-dry weight, of which 13 tons were organic matter and 7 tons were mineral matter and ash. Measurements of similar magnitude in predominantly white pine have been found elsewhere in New England, New York, Pennsylvania, and Minnesota (Appendix, table 3).

The L layer of all plots averaged 0.69 inch thick and ranged from 0.3 to 1.5 inches; the F layer 1.25 inches; ranging from 0.3 to 2.1 inches; the H layer 0.52 inch, ranging from 0 to 1.6 inches. The total thickness of the forest floor averaged 2.46 inches and ranged from 0.6 to 4.7 inches. The L layer made up to 28 percent of the total thickness, the F layer 51 percent, and the H layer 21 percent.

Average oven-dry weights and ranges in pounds per acre of the forest floor and organic matter by layers were:

	Forest floor	
Layer	*Average*	*Range*
L	3,700	1,700 to 12,500
F	20,500	7,500 to 35,100
H	16,900	0 to 63,600
Total	41,000	10,200 to 85,800

	Organic Matter	
Layer	*Average*	*Range*
L	3,500	1,600 to 11,700
F	16,000	3,800 to 29,000
H	6,500	0 to 18,500
Total	26,000	6,000 to 46,400

On a weight basis, the L layer made up 9 percent of the forest floor and 13 percent of the organic matter; the F layer 50 percent of the forest floor and 62 percent of the organic matter; and the H layer 41 percent and 25 percent, respectively. Thus the F layer was the dominant feature of the forest floor. Mineral content was negligible in the L layer, averaging about 5 percent, and relatively small in the F layer, averaging 22 percent; but it was large in the H layer, averaging 62 percent.

Accumulations by Geographic Provinces

Mean total accumulations by geographic provinces were:

	Forest Floor		*Organic matter*
Provinces	*Depth (in.)*	*Weight (lbs./acre)*	*Weight (lbs./acre)*
Western Upland	2.11	36,600	21,000
Connecticut Valley	2,69	34,300	25,300
Eastern Upland	2.57	43,700	27,900
Coastal Plain	2.55	50,600	30,800

From analyses of variance, differences between provinces in forest floor depths and weights were not significant at the 5-percent level (F for depth = 2.05, for weight 1.60, for 5-percent level 2.76). Differences in organic matter were significant at the 5-percent level (F = 3.21). And compared for individual provinces, organic matter differences between the Western and Eastern Uplands and between the Western Upland and Coastal Plain proved to be significant at the 5-percent level.

Accumulations by Parent Materials

Mean total accumulations by parent materials were as follows:

	Forest floor		*Organic matter*
	Depth (in.)	*Weight (lbs./acre)*	*Weight (lbs./acre)*
Sands and gravel	2.59	48,300	29,000
Aeolian or fine-textured outwash	2.50	39,200	26,900
Coarse-textured till	2.05	36,300	17,000
Fine-textured till	2.37	34,400	23,600

Differences between forest-floor depths, from an analysis of variance, were not significant at the 5-percent level (F = 0.96). But differences between forest-floor weights were significant (F = 3.87) as were differences in organic matter weights (F = 3.51); in both analyses the significant difference (5-percent level) was between sands-and-gravel and the fine textured tills, and also for organic matter, between sands-and-gravel and coarse-textured tills.

Thickness, Weight, and Layer Relationships

Mean bulk densities of the total forest floor and its layer were:

L	0.024
F	.072
H	.144
L,F,H	.074

The F and H values are somewhat lower than mean values of 0.11 and 0.22, respectively, from several hardwood and conifer stands in the Northeast (*Trimble and Lull 1956*).

Correlations of forest floor thickness to forest floor weight by layers diminished from the L to H layers; simple correlation coefficients were:

L	0.675**
F	.611**
H	.589**
L,F,H	.570**

**Significant at the 1-percent level.

Linear regressions of predicted weight in pounds (Y) to depth in inches (X) and their standard errors of estimate (S.e.e.) were:

		S.e.e.
L	Y= 5,296X	1,465
F	Y=15,838X	5,761
H	Y=28,551X	11,708
L,F,H	Y=16,474X	13,532

For plots in this study, depths provided only poor estimates of weights: standard errors of estimate ranged from about one-fourth to over one-half of average weights of the layers.

Correlation of forest floor weights to organic-matter weights by layers also diminshed with depth:

L	0.997**
F	.967**
F	.765**
L,F,H	.754**

Predicted organic content weights (Y) in relation to forest floor weight (X) and their standard errors of estimate were:

		S.e.e.
L	Y=0.95X	164
F	Y= .78X	3,740
H	Y= .34X	3,248
L,F,H	Y= .60X	6,618

For plots such as these, organic-matter content of the litter and the total forest floor were estimated fairly well from forest floor weights, the greatest error being in relation to mean layer weights was in the H layer.

Because of the fluctuating nature of the L layer, we did not compute correlations of thicknesses and weights between the

L and F layers. Correlations between the F and H layers were weak and not significant; thickness or weight of these layers could not be estimated from each other.

Influencing Factors

By simple correlation, we calculated the relationships of age, basal area, site index at 50 years, elevation, and soil drainage class to total accumulations of forest floor and organic matter. These factors were selected as those most likely to reflect stand, climate, and soil conditions influencing both production and decomposition of the humus layers. Simple correlation coefficients were:

	Forest floor		*Organic matter weight*
	Depth	*Weight*	
Age	0.334**	0.417**	0.313**
Basal area	.012	–.068	–.083
Site index	–.242*	–.306*	–.391**
Drainage class	.136	.374**	.226
Elevation	–.203	–.218	–.261*

*Significant at the 5% level.

Only age and site index were significantly related to all three of the accumulative variables. Correlations were not strong, age and site index individually accounting for only 6 to 17 percent of the variations in accumulation.

The positive correlation with age was as expected. The negative correlation with site index is supported by recent observations by the senior author that small amounts of forest floor of red pine plantations were associated with better sites. Young (*1954*) and Trimble (*Trimble and Lull 1956*) have also noted thick accumulations of more humus layers on poor sites and smaller amounts on better sites, either because of more rapid decomposition or incorporation. However, as noted by Kittredge (*1948*), others have reported positive correlations between site index and amount of forest floor.

Drainage class was significantly related only to forest floor weight, drier soils having greater accumulation. These dry soils

also generally registered somewhat lower site quality. It seems likely that wet soils (poorly and very poorly drained) might show large accumulations also, but only one wet-soil stand showed a larger accumulation. The negative correlations with elevation may be related to the fact that poorer sites on sandy, gravelly soils in Massachusetts are generally found at lower elevations; however, the correlation of 0.107 between site index and elevation for these plots provided little support for this hypothesis.

The small proportion of the variation in total accumulation accounted for by the above independent variables suggested that one of the forest floor layers might be more highly correlated. To determine this, simple correlation coefficients were computed between each layer and each of the 5 independent variables (Appendix, table 5). Of the 45 correlation coefficients, only 8 were significant:

	Forest floor				
	Depth		*Weight*	*Organic matter*	
	F	*H*	*H*	*F*	*H*
Age	0.261*	0.311*	0.355**	0.290*	—
Basal area	—	—	—	—	−0.244*
Site index	—	—	—	−.256*	—
Drainage class	—	—	.298*	—	—
Elevation	−.367*	—	—	—	—

The L layer was not significantly correlated to any of the stand or environmental variables. Stand age accounted for 4 of the 8 significant coefficients. Generally, thicknesses or weights of individual layers were not as highly correlated as total values.

Multiple Regressions

Multiple regressions were calculated, relating the five site variables to forest floor (Y_1) and organic matter (Y_2) weights:

$$Y_1 = 36.081 + 3.83X_1 - 6.51X_2 - 1.76X_3 - 0.82X_4 + 2.93X_5$$
$$Y_2 = 43.104 + 1.56X_1 - 1.84X_2 - 3.35X_3 - 0.51X_4 + 0.38X_5$$

In these equations X_1 = average stand age divided by 10; X_2 = basal area in square feet per acre divided by 100; X_3 = site

index divided by 10; X_4 = elevation in feet divided by 100; X_5 = drainage class[3]; Y_1 and Y_2 are in thousands of pounds.

Multiple correlation coefficients 0.589** for the forest floor and 0.535** for the organic-matter equations, though significant at the 1-percent level, are still relatively low—the highest accounting for only about 35 percent of the variation in the dependent variable. The low percentage of variability accounted for suggests that some important major factors may not have been included; also, the large natural variation and consequent sampling errors were partially responsible for the low percentage.

Two variables in each regression, age and drainage class in the forest-floor equation and age and site index in the organic-matter regression, proved in t-tests to be statistically significant. The nature of these factors suggests that they act independently in relation to accumulations.

As a matter of interest, we calculated multiple regressions, employing only the three variables that had proved to be significant in simple correlation. And we calculated separate regressions for the 27 plots on fine-textured tills; a multiple regression with weight of the H-layer as the dependent variable was calculated. Correlation coefficients are summarized as:

Dependent variables	*Independent*[4] *variables*	*Forest floor*	*Organic matter*
L,F,H,	A,B,S,D,E	0.589**	0.535**
L,F,H,	A,S,D	.534**	—
H	A,S,D	.445	—
L,F,H	A,S,E	—	.525**
L,F,H sand-gravel	A,B,S,D,E	.560**	.707**
L,F,H tills	A,B,S,D,E	.440**	.476**

Correlation coefficients were not greatly reduced by employing three variables rather than five; the H-layer weight was not as highly correlated as total weight of the forest floor; and plots on sands and gravel yielded highest correlations.

[3] O = very poorly drained, 1 = poorly drained, 2 = somewhat poorly drained, 3 = moderately well drained, 4 = well drained, 5 = somewhat excessively drained, 6 = excessively drained.

[4] A = age, B = basal area, S = site index, D = drainage class, and E = elevation.

Moisture Storage and Drying

Moisture contents, taken periodically at the four sampling sites, are shown in percent by weight in figure 3 and in inches of water in figure 4. Mean maxima and minima, by layers for each of the four sampling areas, are tabulated in the Appendix, table 6, together with the composite averages for all plots. The values are reasonably consistent for all stands.

Maximum moisture observed in the L layer ranged from 124 to 291 percent by weight, averaging 169. Most values ranged from 150 to 170 percent. In percent by volume, the values ranged from 4.0 to 8.3 percent; however, these values were not very reliable because of the difficulty in measuring the L-layer thickness accurately. Minimum values for the L layer ranged from 5.2 to 14.8 percent by weight, averaging 9.5. Thus the maximum absorptive capacity was about 160 percent by weight for the L layer. By volume it was about 5.5 percent.

Values for the F layers followed a similar pattern: maxima by weight ranged from 222 to 318 percent, averaging 258. Minima ranged from 15 to 44 percent by weight, averaging 30. By volume, maxima ranged from 14 to 33 percent, averaging 21, while minima ranged from 1.2 to 3.5 percent, averaging 2.3. These values indicate the high maximum, moisture-holding capacity of F layers: about 230 percent by weight or 18 percent by volume.

Values for H layers were more variable than for L and F layers because of the wide variation in mineral content that caused large fluctuations in the percent-by-weight values. The absorptive capacity of about 24 percent by volume (the difference between an average maximum of 31 percent and an average minimum of 6.5 percent), was even higher than for the F layers.

Maximum moisture content for the total forest floor averaged 205 percent by weight, and the minimum moisture content averaged 27 percent. These were very similar to comparable values of 220 percent and 25 percent reported by Metz (*1958*) for loblolly pine forest floor in South Carolina, and 215 percent

and 30 percent reported by Helvey (*1964*) for hardwood forest floor in North Carolina.

Maximum and minimum water-holding capacities of the layers in the four stands, in inches of water, are given in table 1. The differences between minimum and maximum values for the four stands ranged from 0.39 to 0.46 inches of water for the total forest floor. This amount represents the maximum amount of rain that might be retained by the layers if they were in field-dry condition.

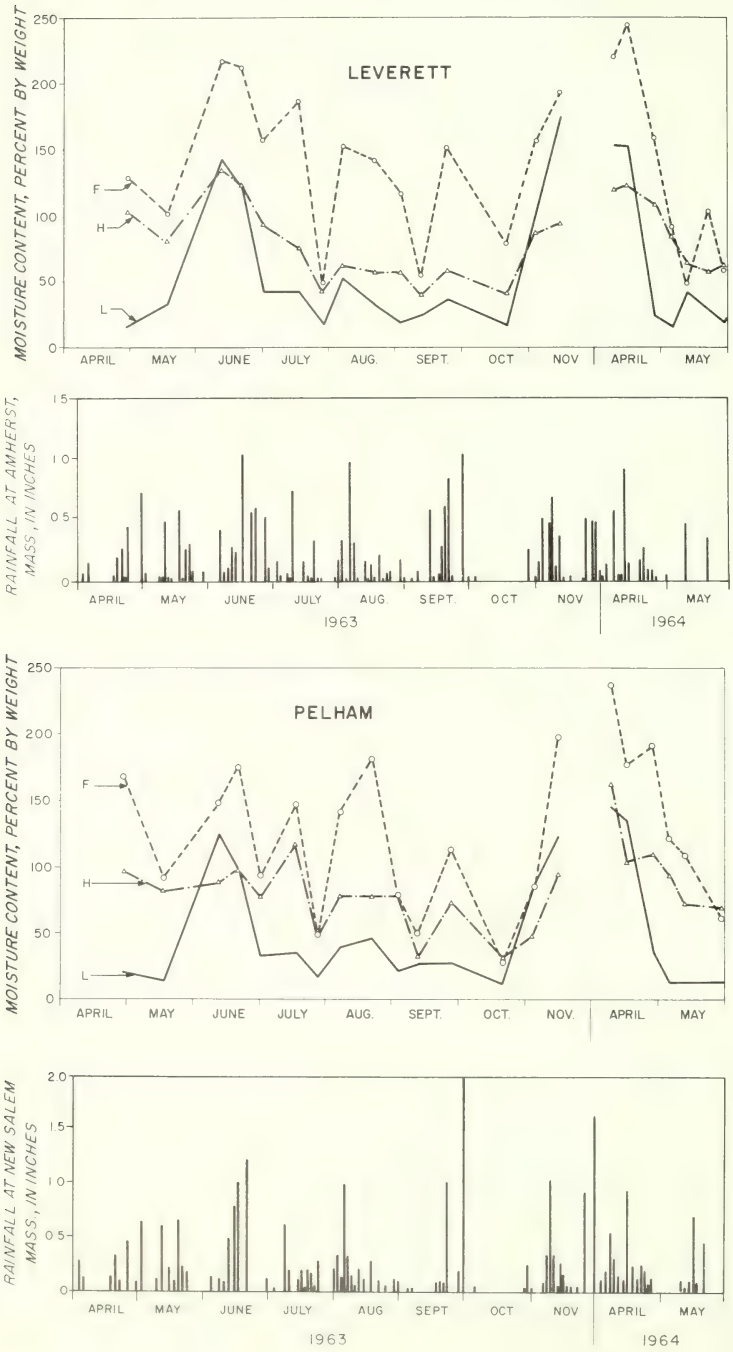
Based on a maximum moisture content of 0.45 inch at Leverett and 0.51 at Pelham, the mean available storage for the 1963 period was 0.22 inch and 0.28 inch respectively. The comparable mean available soil-moisture storage was 2.05 inches, based on a soil-moisture budget with an estimated 4.0 inches total of maximum available storage. On this basis, forest-floor storage constituted about one-ninth of the total available soil-moisture storage. Available forest-floor storage for the days of measurement and comparable available soil-moisture storage are given in figure 5.

The mean available storage of about 0.25 inch during the summer months plus canopy interception of about 0.10 inch (for 0.5 inch of rainfall) could absorb many of the smaller rainfalls. For instance, from May to October about 60 storms occur (based on the 1952-61 record) of which 45 to 75 percent are 0.50 inches or smaller. They account for about one-third of the 6-month rainfall. Many of the smaller storms could be absorbed almost completely by interception of canopy and humus.

Drying rates differed appreciably among the L, F, and H layers, as is evident in figures 3 and 4: the F layers dried more rapidly than the H; the L layers, presumably, dried more rapidly than the F, though sampling periods were too infrequent to show this. Total exchange of moisture also varied by layers. During the 6-month period in 1963, for instance, inches of moisture accretion and depletion were:

	L		*F*		*H*		*LFH*	
	+	−	+	−	+	−	+	−
Leverett	0.08	0.04	0.42	0.35	0.16	0.17	0.60	0.51
Pelham	.07	.04	.72	.55	.32	.31	1.05	.85

Figure 3.—Moisture content of the forest floor in percent by weight, by location, layer, and date.



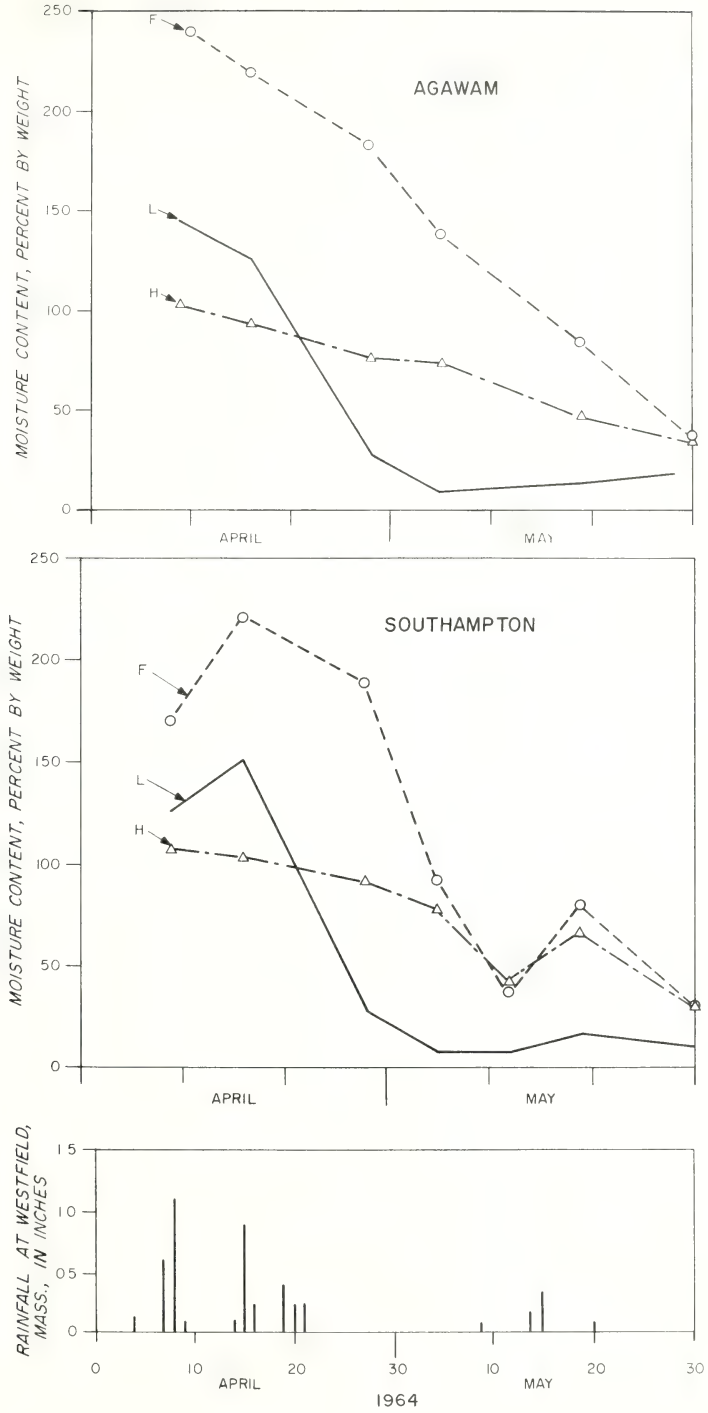
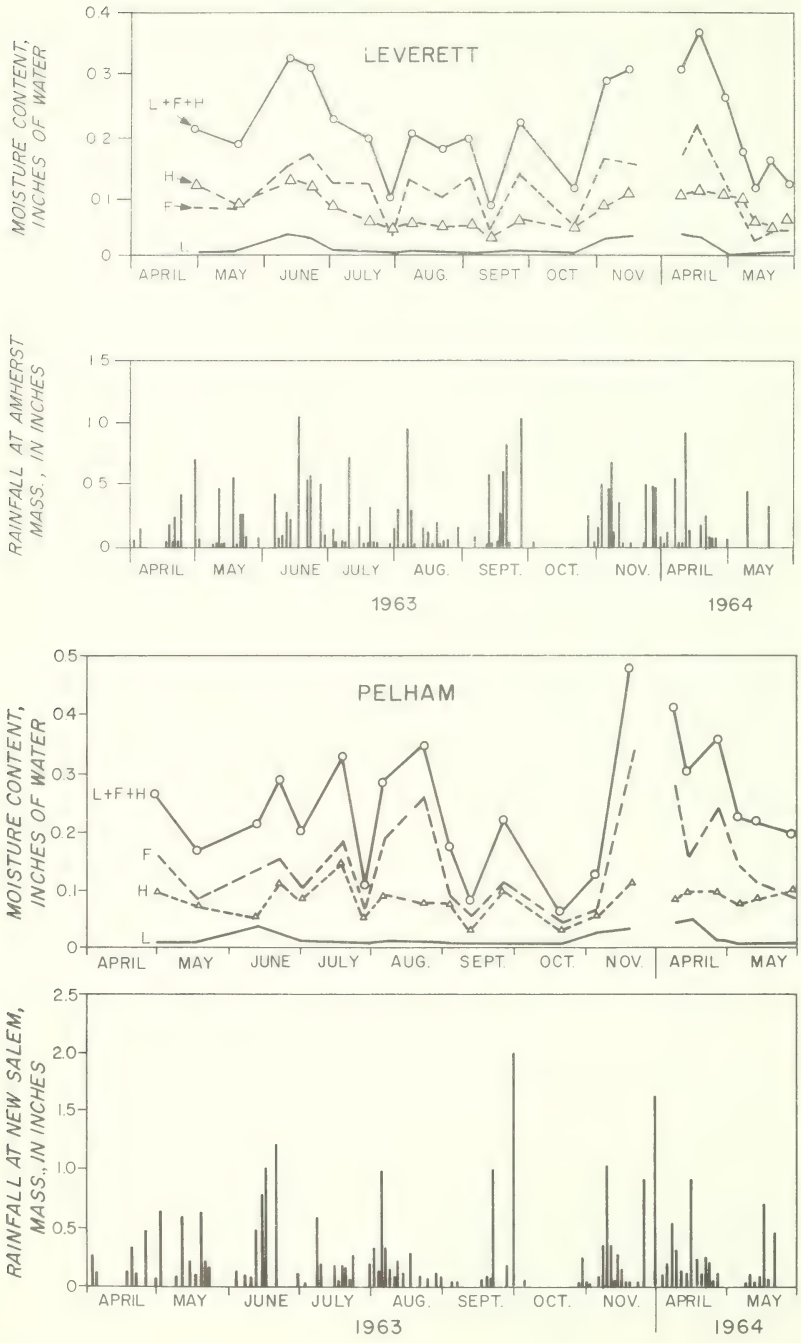

AGAWAM
MOISTURE CONTENT, PERCENT BY WEIGHT
250
200
150
100
50
0
F
L
H
APRIL
MAY
SOUTHAMPTON
MOISTURE CONTENT, PERCENT BY WEIGHT
250
200
150
100
50
0
F
L
H
APRIL
MAY
RAINFALL AT WESTFIELD, MASS., IN INCHES
1.5
1.0
0.5
0
0
10
20
30
10
20
30
APRIL
MAY
1964

Figure 4.—Moisture content of the forest floor in inches of water, by location, layer, and date.



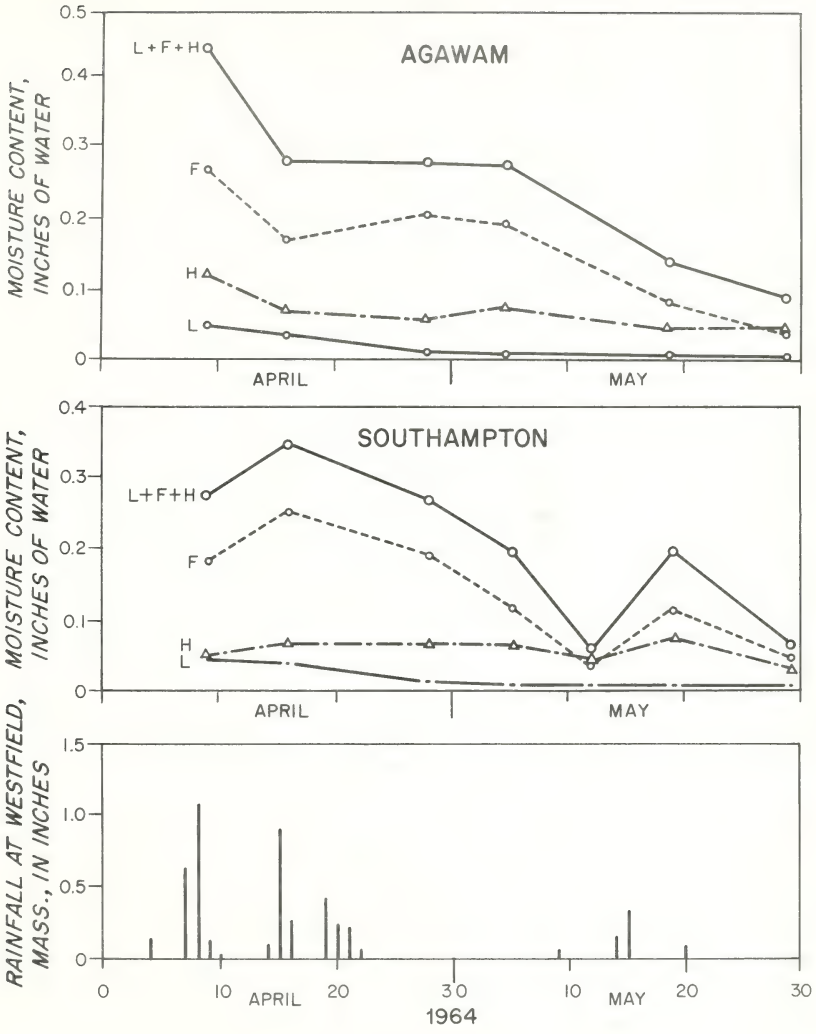
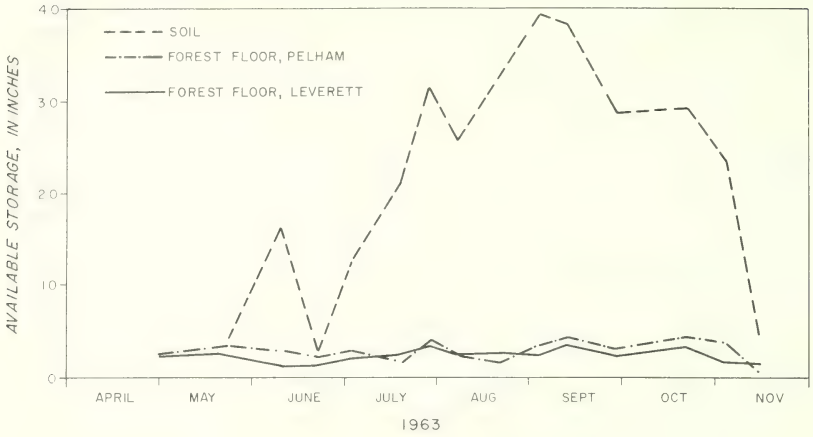

AGAWAM
L+F+H
F
H
L
MOISTURE CONTENT, INCHES OF WATER
0.5
0.4
0.3
0.2
0.1
0
APRIL
MAY
SOUTHAMPTON
L+F+H
F
H
L
MOISTURE CONTENT, INCHES OF WATER
0.4
0.3
0.2
0.1
0
APRIL
MAY
RAINFALL AT WESTFIELD, MASS., IN INCHES
1.5
1.0
0.5
0
0
10
APRIL
20
30
10
MAY
20
30
1964

Figure 5.—Available storage in forest floor and soil on sampling dates from May to November 1963.



Thus the F layer dominated the other two layers both in respect to its magnitude (as previously noted) and in its moisture exchange.

The 6-month growing-season loss of about 0.75 inch suggests an annual loss of 1.0 to 1.25 inches, about one-half the 2-inch annual loss in the southern Appalachians *(Helvey and Patric 1965)*.

Partial wetting of the forest floor took place readily; but complete resaturation required, as Metz (*1958*) found, an extended period of heavy rainfall (figs. 3 and 4). Only a small portion of many rainfalls is absorbed even though the forest floor is not completely saturated. Absorptions of 0.1 to 0.25 inch of rain occurred during rainy periods in the summer but resaturation to the 0.4- to 0.5-inch capacity did not occur even with rains of 1 to 2 inches. Apparently either a good deal of high-intensity rain moves through the layers too rapidly to be absorbed, or the moisture does not have easy access to all absorption surfaces, or some material does not rewet easily once dried.

L layers did not rewet easily during the summer; generally moisture contents stay at very low levels during these months, never approaching the late-fall levels. The L layers did resatu-

rate in the rather extended rainy period in June, 1963. F layers rewetted much more readily, rewetting—even at the lower moisture contents—to quite high levels during the summer rains. H layers did not rewet as readily as F layers.

Forest Floor and Floods

The hydrologic significance of moisture storage in the forest floor in respect to floods can be evaluated only in relation to available storage and the amount of flood-producing rainfall. The amount of storage will depend on antecedent drying. Drying rates of the total forest floor are given in table 2 for those periods in which drying was least affected by rainfall. Estimated rates of soil-moisture drying, based on a daily soil-moisture budget calculated by Thornthwaite's and Mather's procedure (*1957*), are also given. Mean values suggest that during these periods daily loss from the forest floor is about one-fifth of the potential loss.

Synthesizing the eight drying periods into a single curve, on the basis of initial moisture contents, gave a mean curve with these drying rates of the forest floor:

Days	*Loss per day (inches)*
1- 5	0.024
6-10	.016
11-15	.014
16-20	.010

Potential opportunities for antecedent drying of the forest floor and soil, based on the above drying rates and the mean annual number of drying periods of various lengths, May to October, are given in table 3. On an average, only about twice a year would as much as 0.30 inch of moisture be removed between storms—equivalent, depending on initial moisture content, to an available storage of about 0.30 to 0.40 inch. Compared with flood-producing rainfalls, this is a small amount. For instance, characteristic rainfall for severe floods in Massachusetts is around

10 inches in 24 hours over a 200-square-mile area. (*U. S. Department of the Army 1952*). At this intensity of rain, forest-floor storage could then account for 3 to 4 percent of the total, but whether it could reduce the amount of flood runoff by this amount would depend on the available storage of alternative land-uses. From this, apparently, the forest floor of white pine stands in Massachusetts would have very little effect on the volume of runoff yielded from flood-producing rainfalls during the growing season. During the dormant season, when the forest floor would be wetter, its effect on flood volumes would be even less.

Would greater amounts of forest floor be accumulated under older stands of white pine? Measurements suggest this; accumulations in pounds per acre by 10-year age classes were as follows:

Age classes (years)	*All plots*	*Sand & gravel plots*	*Till plots*
31-40	34,400	39,100	26,400
41-50	35,700	46,600	32,200
51-60	44,000	46,200	—
61-70	44,600	50,800	—
71-80	42,100	—	40,200
81-90	63,200	63,200	—
91-100	58,500	55,600	—

Maximum accumulations appear in the 81- to 90-year-old class and are about one-third greater than accumulations at 55 years, the average age of the 65 stands. Even so, this difference, in terms of available water storage, would not amount to much more than 0.10 inch, a difference not great enough to change the above conclusions.

The principal hydrologic function of the forest floor is to permit ready entry of rainfall into the soil. The forest floor's high infiltration rate and its protection of the mineral soil below (both stabilizing it and fostering high percolation rates) give it an importance long recognized. Lowdermilk noted in 1930 that the forest floor is far more important for maintaining percolation capacity than for absorption of rainfall. We did not measure infiltration in this study; but there was no evidence of overland flow or erosion where a forest floor had accumulated.

The role the forest floor plays in flood prevention is a relatively minor one for the forest as a whole. The greatest role of the forest is in the available storage it creates in the soil through transpiration. The greater vegetation of the mature undisturbed forest in relation to other land uses, and its deep root system and low albedo, permit maximum development of available storage for flood-producing rainfalls. This effect on flood runoff, however, can only be evaluated in respect to effects of alternative land uses.

The principal results of this study are:

- The forest floor of 65 white pine stands in Massachusetts averaged 2.5 inches in depth and weighed about 20 tons per acre, of which 13 tons were organic matter.
- The L layer averaged 0.69 inches in thickness, the F layer 1.25, and the H layer 0.52.
- There was a significant difference in organic matter accumulations between the Eastern (27,900 pounds per acre) and Western Uplands (21,000 pounds per acre) and between the Western Upland and the Coastal Plain (30,800 pounds per acre). Difference in forest floor accumulations were not significant.
- Sands and gravels had significantly greater accumulations of forest floor (48,300 pounds per acre) and organic matter (29,000 pounds per acre), than the fine-textured till soils (34,400 and 23,600 pounds per acre, respectively).
- Correlation coefficients of depths to weight of forest floor layers ranged from 0.675** to 0.570**. Correlation of forest floor weights to organic-matter weights ranged from 0.997** to 0.750**. There was little or no correlation between thicknesses of the F and H layers and their weights.
- Multiple regression equations with five independent variables (age, basal area, site index, drainage class, and elevation)

accounted for 30 to 35 percent of the variation in weight of the forest floor and organic matter. Age, site index, and drainage class were the most important variables.

- Maximum moisture storage capacity of the forest floor at four sampling areas ranged from 0.39 to 0.46 inches. The mean daily drying rate for periods least affected by rainfall was 0.014 inch, about one-fifth of the mean daily potential evapotranspiration.
- The forest floor did not resaturate during the summer months, even from rainfalls that exceeded moisture-storage capacities.
- Mean available storage in the forest floor, from May to November 1963, was about 0.25 inch.
- On an average, only about twice a year would as much as 0.30 inch of moisture be removed from the forest floor between storms.
- Forest floor storage could accommodate perhaps 3 to 4 percent of the 10-inch rainfall that produces severe floods in Massachusetts.
- About 20 to 25 forest floor samples are necessary to give mean weights with standard errors that, within 95-percent confidence limits, are equivalent to 10 to 15 percent of the mean; a similar number of moisture-content samples will give means with errors of about 20 to 25 percent.

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Sampling Error

Thickness, weight, moisture content and organic content of the forest floor and its layers are characteristically quite variable and the number of samples needed to estimate them at specified levels of precision is unknown.

Towards this end, data from the Leverett and Agawam sites were analyzed for sampling variation. Standard deviations, coefficients of variations, standard errors, and confidence limits, for forest-floor and organic-matter weights, and moisture contents are given in table 2. Weights for all sampling dates were pooled, giving 24 to 32 replicates, on the assumption that weight changes were negligible over the period of sampling. Moisture-content averages were based on the four samples taken at each date so that replication was at a much lower level. Confidence limits at the 95-percent level were calculated for the various parameters on the basis of 4 and 24 or 32 samples in order to get an idea of precision at both levels.

The forest floor weight at Leverett was estimated quite precisely from 24 samples: on the order of ± 10 percent with only a 5-percent chance of larger error. The 32 samples at Agawam gave smaller errors in the L, F, and total, and a little larger error in the H layer. The error in the H layer weight was apt to be higher than other layers because of the inconsistent amount of mineral matter in the H layer, and the difficulty of judging the H layers boundary with the mineral soil below. Coefficients of variation of 18 and 22 percent were similar to the 20-percent coefficient reported by Helvey and Patric *(1965)* for hardwood forest-floor weights.

Organic-matter weights were no less variable. Coefficients of variation were somewhat higher, although of course they included the additional experimental error in subsampling and ignition of the samples. Confidence limits for means based on only four samples are on the order of 30 to 60 percent of the mean. In plots like these, 20 to 25 samples gave for most purposes satisfactory estimates of forest-floor and organic-matter weights.

The percentage of organic matter in the L and F layers was estimated quite precisely with only four samples — the L within ± 4 percent of the mean percent at the 95 percent confidence level, the F with a probable error of 11 percent of the mean value. The organic content of the H layer was more variable and required about 25 samples to be sure the estimate was as precise as that for the F layer. These data suggest that when sampling forest floor layers to determine total weight, it is necessary to sample much more intensively to estimate weights of the L and F layers than to determine their organic-matter contents. Therefore it is not necessary to run ignitions on all the samples obtained for the L and F layers, which is a definite saving in time and cost.

We anticipated that percentage moisture content of the forest floor would be more variable than its weight because of irregular drying and wetting. However, the data do not indicate that this was so; in fact, in many instances the reverse was true. Table 3 also indicates that per-

centages were least variable at high-moisture contents with 95-percent confidence limits of four sample averages for the L and F layers on the order of 10 and 25 percent of the mean value, and for the H layers up to about 50 percent. At low moisture contents, the errors in percentage of moisture ranged, with four samples, from 40 to 50 percent of the mean percent at the 95-percent confidence limit. Estimates suggest that sample numbers of about 25 will give moisture-percent means that are consistent within 5 to 10 percent of the mean value at high-moisture contents and within 10 to 15 percent at low-moisture contents in pine stands similar to these.

Estimates of total moisture content in inches of water for the forest floor, the value which is perhaps most important in this type of study, are much more variable than either weight or moisture percentage. Apparently both contribute substantially to the variation in total moisture content. Mean values based on four samples, the number taken in this study, had confidence limits at the 95-percent level of about 30 to 90 percent of the mean values. F layers seemed to be more variable in total-moisture content than the L or H layers. Increasing the number of samples to 24 would apparently bring the 95-percent confidence limits for the mean moisture content to within 20 to 25 percent of the mean values. Variability of the mean moisture content for the L, F, and H layers combined was lower than for the most variable horizon, usually the F layer, but not much lower. The variability of the estimation of total moisture contents in the humus layers was so high that we could seldom get means much more precise than ± 10 percent at the 95-percent confidence level. Whether or not this precision can be greatly improved with other sampling designs remains to be seen, but it appears doubtful considering the variability in weight and the inconsistency of drying and wetting conditions from point to point.

Table 3.—*Mean annual number and length of drying periods and associated moisture loss from forest floor and soil*

Periods	Drying days	Moisture loss	
		Forest floor	Soil
No.	*No.*	*Inches*	*Inches*
10	1- 2	0.02-0.05	0.07-0.13
6	3- 4	.07- .10	.20- .27
5	5- 8	.12- .17	.34- .54
3	9-14	.18- .26	.60- .94
2	15-21	.27- .33	1.00-1.41

Table 1.—*Maximum and minimum moisture contents of forest floor layers in four white pine stands, and maximum moisture storage*

Location	Layer	Average thickness	Moisture content		Maximum moisture storage
			Maximum	Minimum	
		Inches	*Inches*	*Inches*	*Inches*
Leverett	L	0.71	0.041	0.002	0.039
	F	1.23	.253	.029	.224
	H	.51	.157	.033	.124
	Total	2.45	0.451	0.064	0.387
Pelham	L	.71	.041	.002	.039
	F	1.43	.295	.033	.262
	H	.56	.173	.036	.137
	Total	2.70	0.509	0.071	0.438
Southampton	L	1.00	.058	.003	.055
	F	1.42	.293	.033	.260
	H	.31	.096	.020	.076
	Total	2.73	0.447	0.056	0.391
Agawam	L	1.01	.059	.003	.056
	F	1.59	.328	.037	.291
	H	.45	.139	.029	.110
	Total	3 .05	0.526	0.069	0.457

Table 2.—*Daily drying rates of forest floor and soil*

Location	Interval	Drying rate per day	
		Forest floor	Soil
		Inches	*Inches*
Leverett	July 17-28, 1963	0.010	0.089
	Sept. 3-12, 1963	.012	.037
	April 16-May 12, 1964	.010	.057
Pelham	July 17-28, 1963	.020	.089
	Aug. 22-Sept. 12, 1963	.013	.050
	April 28-May 5, 1964	.018	.050
Southampton	April 28-May 12, 1964	.013	.069
	May 19-29, 1964	.012	.094
	Mean	0.014	0.067

Table 4.—*Basic data, by plots*

Plot No.	Forest floor								Organic matter weight per acre				Description						
	Thickness				*Weight per acre*								Geog. prov.[1]	Elevation	Soil group[2]	Drainage class[3]	Stand age	Basal area per acre	Site index
	L	F	H	Total	L	F	H	Total	L	F	H	Total							
	In.	*In.*	*In.*	*In.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*		*Ft.*			*Yrs.*	*Sq. Ft.*	*Ft.*
1-4	.5	1.0	.5	2.0	2,106	18,642	16,872	37,620	1,553	9,340	3,919	14,812	WU	1,250	CTT	4	70	192	59
1-5	.5	1.1	.4	2.0	3,620	22,353	17,436	43,409	2,645	14,931	3,885	21,461	WU	1,045	SG	5	37	226	66
1-6	.5	1.5	1.0	3.0	1,904	18,644	25,369	45,917	1,833	14,916	8,798	25,547	WU	1,020	SG	6	70	127	67
1-7	.3	.3	—	.6	3,495	7,472	—	10,967	3,337	3,764	—	7,101	WU	980	FFT	3	36	170	72
1-8	.5	1.0	—	1.5	3,231	15,310	—	18,541	3,129	10,293	—	13,423	WU	730	SG	5	39	194	62
1-9	.5	1.0	—	1.5	4,741	24,096	—	28,837	4,299	16,134	—	20,433	WU	735	FTO	4	39	225	71
2-1	.9	1.4	—	2.3	3,842	22,349	—	26,191	3,687	17,686	—	21,373	WU	470	FTT	4	50	222	77
2-2	.8	1.3	.5	2.6	3,426	27,690	13,541	44,657	3,366	25,959	5,509	34,834	EU	570	SG	5	75	223	61
2-3	.8	1.3	.3	2.4	3,148	35,094	12,574	50,816	2,729	13,166	2,502	18,397	WU	550	CTT	5	71	215	55
2-4	.8	1.1	.6	2.5	2,568	21,122	24,811	48,501	2,484	17,459	10,551	30,494	WU	800	FTO	4	71	242	80
2-5	.8	1.3	1.0	3.1	2,550	19,654	63,637	85,841	2,455	14,529	12,368	29,352	WU	860	SG	6	89	260	65
2-6	.5	1.0	.4	1.9	2,638	18,202	18,962	39,802	2,565	15,341	5,039	22,945	EU	620	SG	6	57	201	55
2-7	.5	1.1	.6	2.2	2,239	15,079	21,154	38,472	2,109	12,320	10,932	25,381	EU	650	SG	6	60	153	54
2-8	.6	1.0	.9	2.5	2,370	15,295	32,876	50,541	2,300	13,841	10,396	26,537	EU	560	SG	3	88	183	58
2-9	.8	1.1	.6	2.5	3,569	18,622	31,183	53,374	3,464	14,118	12,444	30,026	EU	570	SG	5	87	161	49
2-10	.5	1.0	.5	2.0	2,095	22,859	10,534	35,488	2,043	10,852	1,696	14,591	EU	1,020	FTT	3	41	196	60
2-11	.5	.7	.6	1.8	3,260	15,468	20,779	39,507	3,145	11,439	7,786	22,370	WU	450	FTT	2	41	164	68
2-13	.6	1.1	.6	2.3	2,098	18,497	15,193	35,738	1,971	14,246	5,252	21,469	EU	920	CTT	5	40	166	60
2-14	.4	.9	.6	1.9	1,653	16,903	13,923	32,479	1,597	14,052	6,747	22,396	EU	650	SG	3	51	164	51
2-15	.5	1.6	.4	2.5	1,678	28,226	8,122	38,026	1,608	25,386	4,654	31,648	EU	570	SG	2	68	248	66
2-17	1.1	1.0	.8	2.9	7,949	19,719	22,546	50,214	7,626	16,893	7,547	32,066	EU	1,050	SG	6	38	135	59
2-18	.6	2.1	—	2.7	2,622	34,616	—	37,238	2,555	28,269	—	30,824	CV	230	SG	5	43	143	65
2-19	1.3	1.3	.8	3.4	10,280	34,327	18,927	63,534	9,387	28,977	8,006	46,370	EU	1,000	FTT	5	65	187	56
2-21	.4	.6	—	1.0	1,694	8,477	—	10,171	1,567	4,468	—	6,035	EU	650	FTT	2	38	168	67
3-1	1.5	1.6	1.6	4.7	5,251	10,624	14,563	30,438	5,002	9,311	6,255	20,568	EU	660	FTT	3	48	206	65
3-2	.6	.9	1.1	2.6	4,515	15,077	9,760	29,352	4,347	13,345	6,755	24,447	WU	455	FTO	3	66	309	72
3-4	.9	.8	1.5	3.2	5,352	8,620	18,948	32,920	5,250	7,967	13,296	26,513	CV	240	SG	6	69	256	54
3-5	1.0	1.0	—	2.0	2,976	16,648	—	19,624	2,894	10,160	—	13,054	WU	1,440	FTT	1	34	151	72
3-6	1.1	1.1	1.5	3.7	4,781	13,185	20,596	38,562	4,637	12,386	15,113	32,136	EU	1,070	FTT	4	44	203	61
3-7	1.0	.6	.4	2.0	3,495	19,054	12,927	35,476	3,400	14,026	4,388	21,814	WU	1,025	FTT	5	44	240	55

3-8	1.1	.9	1.0	3.0	6,343	8,480	23,968	38,791	6,196	8,129	14,467	28,792	EU	980	FTT	3	49	205	57
4-1	.9	1.0	.4	2.3	3,570	15,840	42,649	62,059	3,476	12,070	8,118	23,664	EU	725	SG	5	41	214	67
4-2	1.0	1.1	.9	3.0	2,647	17,989	21,840	42,476	2,568	15,870	10,938	29,376	CV	220	FTO	4	38	168	61
4-3	1.0	1.0	.6	2.6	3,627	13,501	—	17,128	3,424	9,468	—	12,892	CV	200	FTO	4	62	259	73
4-4	.8	1.0	.3	2.1	5,095	14,226	10,573	29,894	4,924	12,744	3,162	20,830	CV	380	FTT	4	38	117	65
4-5	.8	1.4	.5	2.7	3,738	17,627	32,291	53,656	3,618	15,620	12,161	31,399	CV	220	FTO	4	42	145	60
4-6	.5	.6	—	1.1	2,741	11,709	—	14,450	2,662	6,434	—	9,096	WU	760	FTT	3	45	205	71
4-7	1.0	1.5	—	2.5	4,504	22,414	—	26,918	4,379	20,794	—	25,273	CV	200	(Peat)	0	46	176	56
4-8	1.0	1.0	.5	2.5	3,253	16,056	21,705	41,014	3,169	14,602	10,290	28,061	WU	1,090	FTT	4	48	217	61
4-9	1.0	1.6	.4	3.0	3,959	31,719	10,097	45,753	3,848	27,471	4,972	36,291	WU	1,160	FTT	4	72	191	55
5-1	.5	1.0	.5	2.0	1,777	22,149	10,660	34,586	1,726	20,845	8,890	31,461	EU	820	FTT	5	73	212	51
5-2	.5	1.3	.3	2.1	3,402	20,296	2,745	26,443	3,304	18,238	2,366	23,908	EU	860	SG	6	45	159	54
5-3	.5	1.0	.4	1.9	2,234	18,243	14,389	34,866	2,130	16,785	9,522	28,437	EU	950	SG	6	34	156	53
5-4	1.3	1.1	.5	2.9	10,021	18,010	13,188	41,219	9,714	15,227	6,125	31,066	EU	1,100	FTT	4	40	158	58
5-5	.6	1.3	—	1.9	3,644	12,751	—	16,395	3,311	8,078	—	11,389	EU	760	FTT	3	72	237	70
5-6	.5	1.0	—	1.5	1,828	19,323	—	21,151	1,605	11,620	—	13,225	EU	820	CTT	5	45	156	66
5-7	.6	1.5	.6	2.7	3,282	23,883	51,676	78,841	3,191	19,069	9,173	31,433	EU	400	SG	6	51	198	64
5-9	.5	2.0	—	2.5	2,983	28,329	—	31,312	2,883	18,387	—	21,270	EU	1,000	FTT	4	52	170	59
5-10	.5	1.6	.4	2.5	2,422	20,167	11,341	33,930	2,327	17,740	4,122	24,189	EU	575	FTO	4.5	57	202	61
5-11	.5	1.5	.5	2.5	4,417	24,721	17,029	46,167	4,232	21,038	9,279	34,549	EU	520	FTT	4.5	39	177	62
5-12	.5	1.0	—	1.5	2,829	19,654	—	22,483	2,835	14,443	—	17,278	EU	910	FTT	5	45	216	60
5-13	.5	2.0	.5	3.0	3,824	30,190	23,240	51,254	3,753	25,824	7,460	37,037	EU	605	FTO	4	55	241	61
5-16	.5	1.5	1.0	3.0	3,447	28,464	14,765	46,676	3,316	24,726	7,158	35,200	EU	730	SG	3	91	284	68
5-17	.5	1.5	.8	2.8	2,248	30,983	31,087	64,318	2,094	25,388	11,413	38,895	EU	770	FTT	4	91	213	64
6-1	.5	1.0	.5	2.0	3,692	17,738	21,560	42,990	3,613	15,700	5,146	24,459	EU	320	SG	6	54	223	58
6-2	.5	2.0	.5	3.0	2,606	18,443	14,919	35,968	2,508	16,971	10,736	30,215	EU	330	SG	6	52	194	58
6-3	.5	2.0	.5	3.0	3,765	33,074	26,452	63,291	3,593	27,807	8,121	39,521	EU	210	SG	6	62	172	47
6-4	.8	1.8	.5	3.1	4,127	19,119	30,785	54,031	4,010	15,193	9,664	28,867	EU	450	FTT	4	75	157	63
6-6	1.3	1.1	1.1	3.5	12,473	20,844	40,562	73,879	11,665	15,698	11,564	38,927	EU	210	SG	6	65	143	56
6-7	.6	1.8	.8	3.2	3,381	17,983	26,907	48,271	3,075	13,216	18,459	34,750	EU	206	SG	0	39	92	57
6-11	.5	2.0	.5	3.0	2,335	32,980	29,154	64,469	2,231	19,858	10,626	32,715	EU	295	SG	6	96	136	56
7-4	.5	1.8	.5	2.8	5,402	25,240	30,274	60,916	5,210	16,475	6,462	28,147	CP	90	SG	6	43	200	54
7-6	.5	1.8	.3	2.6	2,643	20,301	8,586	31,530	2,560	16,267	3,462	22,289	CP	25	FTO	4	47	201	60
7-11	.5	1.8	.5	2.8	4,102	30,835	19,948	54,885	3,973	26,217	6,669	36,859	CP	100	SG	5	55	160	52
10-6	.5	.9	.6	2.0	3,358	26,781	24,901	55,040	3,198	20,832	11,832	35,862	CP	40	FTO	2	36	165	70

[1]Geographical province. WU=Western Upland, CV=Connecticut Valley, EU=Eastern Upland, CP=Coastal Plain.
[2]Soil group: SG=sands and gravels, CTT=coarser textured till, FTO=fine-textured outwash, FTT=fine-textured till.
[3]Drainage class: O=very poorly drained, 1=poorly drained, 2=somewhat poorly drained, 3=moderately well drained, 4=well drained, 5=somewhat excessively drained, 6=excessively drained.

Table 5.—*Standard deviations, standard errors of the mean, and coefficients of variations for forest-floor and organic matter weights, and moisture contents of samples, at Leverett (LEV) and Agawam (AG), Massachusetts*

Location	Variable	Number of observations	Mean	Standard deviation	Coefficient of variation, percent	Standard error* 24 or 32 sample mean	Standard error** 4 sample mean	T_{05} confidence limits as percent of mean	
								24 or 32 sample mean	4 sample mean
				FOREST FLOOR					
				Pounds per acre					
LEV	L	24	7,394	1,885	26	375	942	10.0	40
LEV	F	24	24,809	5,109	21	1,043	2,554	8.7	33
LEV	H	24	23,330	6,340	27	1,290	3,170	11.0	35
LEV	L,F,H	24	55,533	9,740	18	1,990	4,870	7.4	28
AG	L	32	5,000	1,126	22	199	563	8.1	36
AG	F	32	18,116	3,057	17	540	1,528	6.1	27
AG	H	32	24,917	10,306	41	1,822	5,153	15	66
AG	L,F,H	32	48,037	10,580	22	1,870	5,290	7.9	35
				ORGANIC MATTER					
				Pounds per acre					
LEV	L	24	6,877	1,758	26	359	879	11.0	41
LEV	F	24	20,197	6,350	31	1,296	3,175	13.0	50
LEV	H	24	8,547	3,523	41	719	1,762	17.0	66
LEV	L,F,H	24	35,620	8,612	24	1,758	4,306	10.0	38
				ORGANIC MATTER					
				Percent					
LEV	L	24	92.96	2.12	2.3	0.4	1.1	1.0	4
LEV	F	24	80.95	5.63	7.0	1.2	2.8	3.0	11
LEV	H	24	37.25	9.32	25.0	1.9	4.7	11.0	40
				FOREST FLOOR					
				Moisture percentage					
LEV May 29, 1964	L	4	19.8	5.7	22	1.2	2.8	12	45
LEV May 29, 1964	F	4	38.6	13.5	36	2.7	6.7	15	55
LEV May 29, 1964	H	4	34.7	8.7	25	1.8	4.3	10	40

LEV May 29, 1964	L	4	13.2	3.2	24	0.7	1.6	10	39
LEV May 29, 1964	F	4	84.8	28.7	34	5.9	14.4	14	54
LEV May 29, 1964	H	4	46.9	9.9	21	2.0	5.0	12	44
LEV April 16, 1964	L	4	126.2	13.1	10	2.7	6.6	4.4	16
LEV April 16, 1964	F	4	219.5	33.3	15	6.8	16.7	6.4	24
LEV April 16, 1964	H	4	93.6	11.4	12	2.3	5.7	5.2	19
LEV April 9, 1964	L	4	145.0	8.7	6.0	1.8	4.4	2.6	9.6
LEV April 9, 1964	F	4	240.3	38.8	16	7.9	19	6.8	26
LEV April 9, 1964	H	4	102.9	33.7	33	6.9	17	13.8	52

FOREST FLOOR

Moisture content, inches

LEV May 29, 1964	L	4	0.0065	0.0034	53	0.0007	0.0017	22	83
LEV May 29, 1964	F	4	.0417	.0176	42	.0036	.0088	17	67
LEV May 29, 1964	H	4	.0454	.0102	23	.0021	.0051	9.5	36
LEV May 29, 1964	L,F,H	4	.0935	.0193	21	.0039	.0096	8.7	33
LEV May 19, 1964	L	4	.0039	.0013	32	.0002	.0006	13	49
LEV May 19, 1964	F	4	.0892	.0436	47	.0089	.0218	21	78
LEV May 19, 1964	H	4	.0484	.0195	40	.0040	.0097	17	64
LEV May 19, 1964	L,F,H	4	.1414	.0573	40	.0117	.0287	17	64
LEV April 16, 1964	L	4	.0378	.0089	24	.0018	.0045	10	38
LEV April 16, 1964	F	4	.2172	.1014	47	.0207	.0507	20	74
LEV April 16, 1964	H	4	.0715	.0155	22	.0031	.0077	9.1	34
LEV April 16, 1964	L,F,H	4	.3265	.0961	29	.0196	.0481	12	47
LEV April 9, 1964	L	4	.0480	.0134	28	.0027	.0067	12	44
LEV April 9, 1964	F	4	.2671	.1471	55	.0300	.0736	23	88
LEV April 9, 1964	H	4	.1284	.0655	51	.0134	.0328	22	81
LEV April 9, 1964	L,F,H	4	.4447	.2120	48	.0433	.1060	20	76

Notes: T_{05} for 3 d.f. — 3.18, T_{05} for 23 d.f. — 2.07, T_{05} for 31 d.f. — 2.04.

*Standard errors are estimated at N=24 for variable with four observations, are actual values for variables with 24 and 32 observations.

**Standard errors for four-sample means are estimates for variables with 24 and 32 observations These errors are actual values for variables with four observations.

L,F,H=Litter, fermentation, and humidification layers of the forest floor.

Table 6.—*Forest floor thicknesses and weights in New England, New York, Pennsylvania, and Minnesota*

Location	Portion of forest floor measured	Forest floor		Age of stand	Reference
		Thickness	Oven-dry weight		
		Inches	*Pounds*	*Years*	
Connecticut River watershed	F,H	2.4	—	70	Morey 1942
Pennsylvania	F,H	1.3 to 4.3	—	virgin stands	Lull 1959
New Hampshire	F,H	1.4 and 2.3			
Massachusetts	L	0.6	—	about 50 yrs.	Cline and Spurr 1942
	F	0.8	—		
	H	0.7	—		
New Hampshire	L,F,H	—	93,158	100	Lunt 1932
Connecticut	L,F,H	—	21,590	27	
Syracuse, N. Y.	L	—	2,875	18	Day 1940
	F	—	9,232		
	H	—	12,108		
Phoenix, N. Y.	L	—	2,333	31	
	F	—	14,029		
	H	—	16,262		
Minnesota	L	—	3,476	250	Alway, Methley, and Younge 1933
	F	—	24,970		
	H	—	40,910		

Table 7.—*Thickness, oven-dry weight, and organic matter content of forest floor layers by geographical provinces and soil parent material groups*

Horizon	Overall average and standard deviation	Average and standard deviation by geographical province				Average and standard deviation by soil parent material groups			
		Western Upland	Connecticut Valley	Eastern Upland	Coastal Plain	Sands and gravel	Aeolian or fine-textured outwash	Coarse-textured till	Fine-textured till
				THICKNESS OF FOREST FLOOR					
				Inches					
L	0.69±0.26	0.69±0.23	0.87±0.15	0.68±0.30	0.50±0.00	0.63±0.22	0.67±0.21	0.60±0.14	0.79±0.34
F	1.25±0.40	1.02±0.34	1.27±0.44	1.33±0.39	1.58±0.45	1.36±0.40	1.28±0.40	1.10±0.14	1.13±0.42
H	0.52±0.38	0.40±0.38	0.54±0.53	0.57±0.36	0.48±0.13	0.60±0.33	0.55±0.30	0.35±0.27	0.45±0.46
Total	2.46±0.67	2.11±0.68	2.69±0.35	2.57±0.69	2.55±0.38	2.59±0.51	2.50±0.45	2.05±0.40	2.37±0.92
				FOREST FLOOR WEIGHT					
				Hundreds of pounds per Acre					
L	37± 20	33± 8	39± 11	40± 25	39± 12	37± 22	34± 8	23± 6	41± 22
F	205± 68	194± 67	184± 83	208± 66	258± 44	215± 64	207± 52	229± 82	186± 77
H	169±133	139±159	119±128	191±123	209± 92	232±144	157±112	112± 76	116±103
Total	410±158	366±177	343±117	437±154	506±130	483±156	392±129	363±121	344±150
				ORGANIC MATTER WEIGHT					
				Hundreds of pounds per Acre					
L	35± 19	29± 8	38± 10	37± 23	38± 11	35± 20	33± 7	20± 5	39± 21
F	160± 58	135± 52	158± 70	167± 57	200± 47	174± 54	169± 43	121± 44	144± 69
H	65± 47	45± 43	57± 62	74± 44	71± 34	81± 41	67± 47	29± 23	53± 50
Total	260± 85	210± 78	253± 66	279± 83	308± 69	290± 58	269± 74	170± 37	236±106

Table 8.—*Correlation of thickness and weight of the total forest floor and its layers with stand age, basal area, site index, drainage class, and elevation*

Item	Age	Basal area	Site index	Drainage class	Elevation
			DEPTH		
Total floor	0.334**	0.012	−0.242	0.136	−0.203
L	−0.014	0.011	−0.017	0.012	0.146
F	0.261*	−0.137	−0.225	0.111	−0.367*
H	0.311	0.116	−0.212	0.094	−0.049
			WEIGHT		
Total floor	0.417**	−0.068	−0.306**	0.374**	−0.218
L	−0.090	0.097	−0.139	0.104	0.020
F	0.109	−0.011	−0.226	0.192	−0.158
H	0.355**	−0.052	−0.221	0.298*	−0.188
			WEIGHT		
Total organic content	0.313**	−0.083	−0.391**	0.226	−0.261*
L	−0.090	−0.100	−0.144	0.117	−0.036
F	0.290*	0.015	−0.256*	0.201	−0.212
H	0.117	−0.244*	−0.231	0.019	−0.171

Table 9.—*Observed moisture content, in percent, by layers*

By weight						By volume					
Maximum			Minimum			Maximum			Minimum		
L	F	H	L	F	H	L	F	H	L	F	H
					LEVERETT						
254.4	317.5	163.5	10.2	36.0	37.8	7.30	20.7	34.6	0.24	2.54	7.96
171.4	272.4	155.5	12.9	30.8	32.0	7.18	18.8	35.4	.34	2.60	7.73
170.8	259.2	153.3	14.8	41.1	28.4	6.78	18.6	29.2	.30	2.42	4.68
164.9	246.4	148.6	14.0	43.7	26.8	6.06	17.3	27.2	.24	2.20	6.78
					PELHAM						
163.7	294.5	237.0	9.7	15.2	15.2	8.32	33.2	39.6	0.22	1.20	4.00
159.5	273.9	176.9	8.9	23.7	23.4	7.12	32.2	34.5	.24	1.22	4.90
158.2	257.0	179.3	10.4	22.0	29.9	7.49	19.1	30.9	.23	1.89	6.31
153.8	250.2	168.0	10.9	22.7	29.3	6.33	25.2	28.4	.27	2.84	6.40
					SOUTHAMPTON						
291.3	247.2	137.5	5.2	24.2	16.0	4.76	21.1	34.1	0.15	2.06	4.22
149.4	235.1	118.4	6.2	25.8	16.3	4.54	18.5	29.3	.17	2.10	5.47
123.9	232.3	108.8	7.2	29.8	31.8	4.34	18.2	27.4	.20	2.76	7.07
123.6	222.3	105.5	8.0	31.1	32.0	4.03	16.0	27.3	.25	3.03	9.80
					AGAWAM						
150.5	296.6	138.7	8.4	26.8	31.0	4.66	24.4	38.6	0.25	1.64	5.61
149.6	253.8	117.0	8.8	32.6	24.8	4.59	17.6	29.0	.28	2.22	6.98
147.8	235.3	105.9	7.9	37.2	38.3	4.70	15.2	26.8	.30	2.89	7.70
—	233.3	—	8.3	—	37.3	4.40	14.3	24.9	.31	3.52	8.40
					AVERAGE VALUES FOR ALL PLOTS						
168.9	257.9	147.7	9.5	29.5	28.1	5.79	20.6	30.8	0.25	2.32	6.50

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Do small mammals and birds affect REPRODUCTION of SPRUCE and FIR?

by Arthur C. Hart
Herschel G. Abbott
Edward R. Ladd

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Do small mammals and birds affect REPRODUCTION of SPRUCE and FIR?

WHY FIR NOT SPRUCE?

AFTER BEING CUT, many spruce-fir stands in the Northeast reproduce to fir rather than spruce. Why? One reason for this may be that wildlife prefer to feed on the seeds and seedlings of spruce rather than fir, so that a smaller proportion of spruce becomes established.

A recent study of the seed-eating habits of mice and voles showed that white spruce seed were taken in preference to balsam fir seed in a ratio of 70 to 1 on the basis of seed weight.[1] The animals were given free access to an unlimited supply of seeds exposed in a small area. This mouse and vole population, which ranged from 15 to 30 animals per acre, consumed more seed than normally is produced in a natural seed crop. However, the concentration of large amounts of seed in a small area may have resulted in unnatural feeding.

To determine the influence of small mammals and ground-feeding birds on spruce-fir regeneration under more natural conditions, we began a new study on the Penobscot Experimental Forest in 1961.

[1] Abbott, Herschel G., and Arthur C. Hart. MICE AND VOLES PREFER SPRUCE SEEDS. U. S. Forest Serv. NE. Forest Exp. Sta., Sta. Paper 153. 12 pp., illus. Upper Darby, Pa. 1960.

STUDY METHODS

A 3-acre area in a mature spruce-fir stand on a well-drained glacial till soil was used for the study. About half of the volume had been cut for pulpwood, leaving 850 cubic feet per acre in seed-bearing dominant and codominant trees. They were well distributed over the area. About half of these trees were spruce, a third fir, and the rest white pine and northern white-cedar. A 2-acre block laid out within the cut area was divided by a grid with 80 stations that were 36.9 feet apart.

To observe the number of spruce and fir germinants that appeared under different degrees of protection against mice and birds, we installed forty 1/2-milacre sample plots in late August 1961. The plots were 7.26 feet long by 3 feet wide. Ten were unprotected controls, marked only by corner stakes (treatment I); the other 30 plots were protected by exclosures constructed of 1/2-inch mesh hardware cloth on wooden frames. We used three types of exclosures for treatments II-IV:

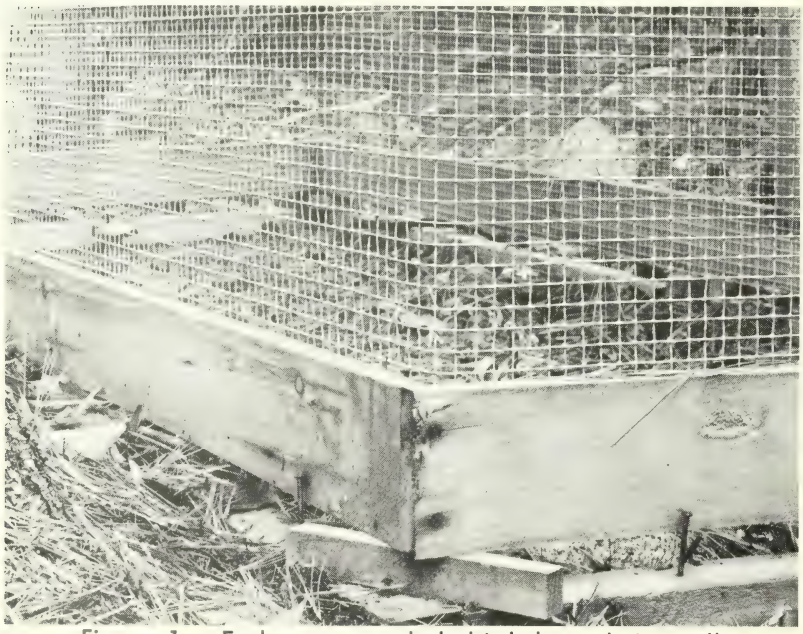

Figure 1. — Exclosure to exclude birds but admit small mammals.

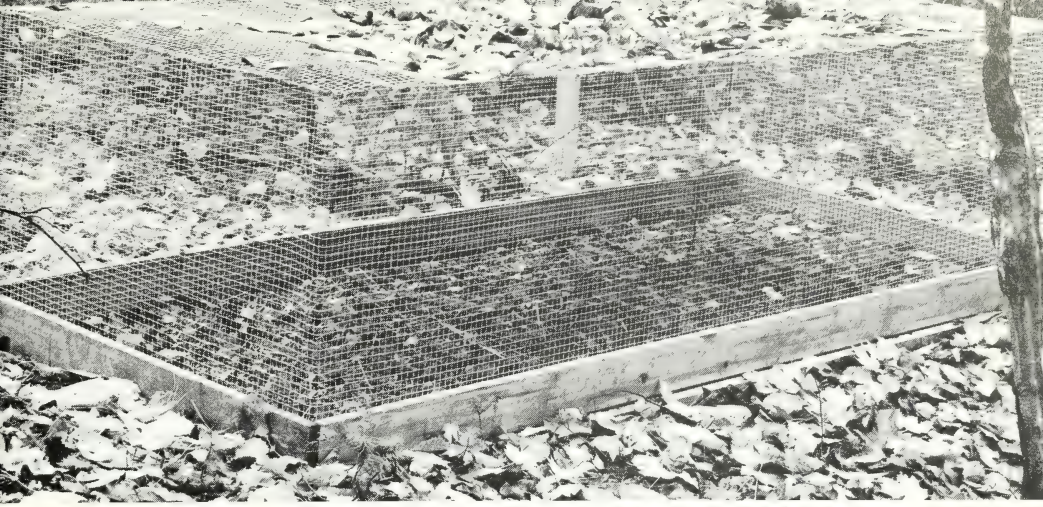

Figure 2. — Exclosure to exclude both small mammals and birds.

- Treatment II—Birds excluded; accessible to small mammals (fig. 1).
- Treatment III—Both birds and small mammals excluded (fig. 2).
- Treatment IV—Small mammals excluded; accessible to birds (fig. 3).

Each treatment comprised 10 plots. Locations for the 40 plots were systematically distributed over the area at or near every other grid station. Treatments were assigned at random to these locations. All exclosures were placed on 2-by-2-inch wooden bases on mineral soil to cut off any small mammal burrows in the duff (figs. 2 and 3). The bird exclosures were elevated on 1-inch blocks to allow small mammals to enter at the bottom (fig. 1).

All spruce and fir seedlings less than 3 inches high were clipped and removed from each of the 40 sample plots at the time of establishment. The number of newly germinated seedlings in each plot was recorded at the end of each growing season before hardwood leaf-fall. Small colored wooden dowels were placed beside each seedling, a different color marked each year's crop.

A census of small mammals was made each year for 4 years:

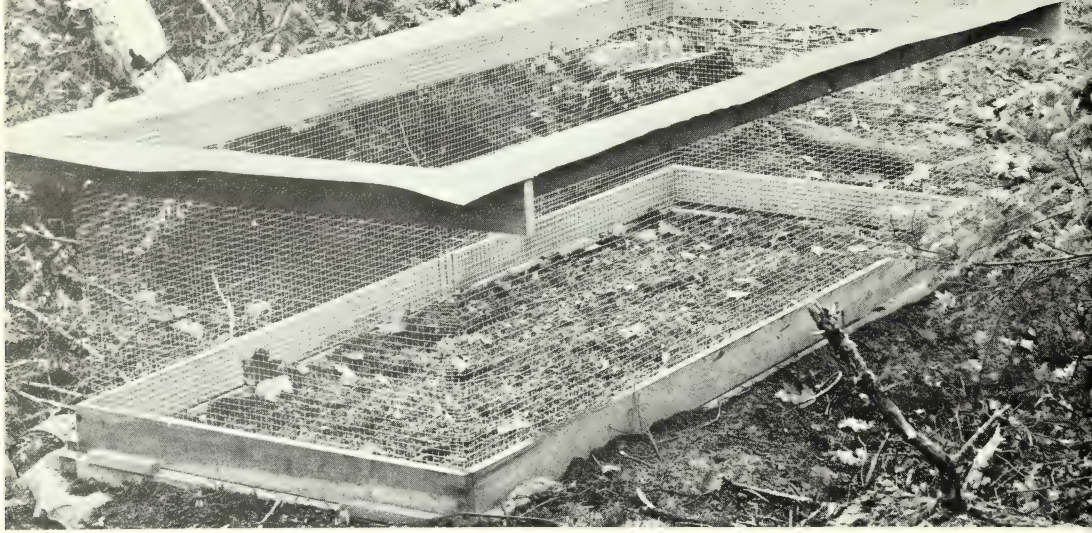

Figure 3. — Exclosure to exclude small mammals but admit birds.

In August before seedfall, again in October after most seedfall had occurred, and again in May before the young animals of the year had entered the mobile population. Eighty Sherman live traps,[2] baited with a mixture of peanut butter and rolled oats, and containing cotton for nesting material, were distributed in the grid pattern. Each trap was placed at the most suitable location within a 5-foot radius of the stake marking a grid coordinate. Such spots included the immediate vicinity of rocks, stumps, slash, and other debris offering cover.

The traps were checked daily in the early morning. Caught animals were identified by species, marked by toe clipping according to a code, and released. Trapping continued until no unmarked animals were taken; this required 4 to 9 consecutive days.

An estimate of the bird population was made at the same time. Nine standard 4-shelf, ¾-inch mesh mist nets, each about 7 feet wide and 36 feet long, were erected in openings with the net bottom placed as close as possible to the forest floor. Nets were erected in the morning, tended on a 1-to-2-hour schedule, and taken down in the evening. Trapped birds were identified, leg-

[2] The Sherman small mammal live traps are made of galvanized sheet metal and have a spring-loaded entrance door that is triggered when an animal enters the trap (Mention of a particular product does not imply endorsement by the U. S. Department of Agriculture.)

banded, and released. Netting periods for birds coincided with the days when the small-mammal censuses were conducted.

Twenty 3-by-3-foot seed traps were distributed at random among the forty ½-milacre sample plots. Collections were made in November before snowfall, and again in May after snowmelt. Spruce and fir seeds were separated from each seed trap collection and counted.

RESULTS AND DISCUSSION

The population of deer mice and boreal red-backed voles—the principal seed eaters among the small mammals captured—ranged from 9 to 20 per acre in August and 10 to 16 in October (table 1) for each of the 4 years 1961 to 1964. The major species of seed-eating birds trapped on the study area also are shown in table 1.

Total estimated spruce seedfall per acre per year ranged from about 55,000 to 1,164,000 for the years 1961 to 1964. Fir seedfall ranged from about 127,000 to 1,385,000 (table 2). Total estimated viable seed per acre ranged from 9,000 to 509,000 for spruce and from 3,000 to 568,000 for fir.

The total number of spruce germinants found in plots accessible to small mammals (treatments I and II) was slightly greater than in the plots where these animals were excluded (treatments III and IV) (table 3). Thus, under the conditions of this study, no evidence was produced to indicate that small mammals affect the regeneration of spruce by feeding upon its seeds.

Because small mammals showed a marked preference for spruce seeds in previous investigations, our results raise some doubts about our experimental techniques. The design or the presence of the exclosures or some unnatural condition on the plots—like lack of cover—may have discouraged the mice and voles from entering the plots because food was ample elsewhere. Uncontrolled study variables, like uneven natural seedfall, also may have confounded the results. More studies like this are needed to fully answer the question "Do small mammals affect spruce-fir reproduction?" Such studies probably should employ

Table 1. Known number of small mammals and seed-eating birds on 2 acres at various census dates

Species	1961		1962			1963			1964		
	Aug.	Oct.	May	Aug.	Oct.	May	Aug.	Oct.	May	Aug.	Oct.
SMALL MAMMALS											
Woodland jumping mouse (*Napaeozapus insignis*)	4	0	0	0	0	0	3	0	0	1	0
Deer mouse (*Peromyscus maniculatus*)	1	4	2	1	3	0	13	4	2	8	2
Red-backed vole (*Clethrionomys gapperi*)	12	17	4	18	18	7	16	18	1	31	30
Short tailed shrew (*Blarina brevicauda*)	2	0	0	1	0	0	0	1	0	0	0
Masked shrew (*Sorex cinereus*)	0	0	0	2	0	0	0	0	0	0	0
Total	19	21	6	22	21	7	32	23	3	40	32
SEED-EATING BIRDS											
Slate-colored junco (*Junco hyemalis*)	4	0	2	2	5	4	0	0	0	2	2
Black-capped chickadee (*Parus atricapillus*)	6	7	0	3	5	0	4	0	4	3	0
Red-breasted nuthatch (*Sitta canadensis*)	6	3	0	4	0	6	4	0	0	1	0
White-breasted nuthatch (*Sitta carolinensis*)	0	0	0	0	1	0	0	0	0	0	0
Purple finch (*Carpodacus purpureus*)	0	0	0	0	2	2	0	0	0	0	0
White-throated sparrow (*Zonotrichia albiocollis*)	0	0	8	1	1	2	0	0	1	0	4
Total	16	10	10	10	14	14	8	0	5	6	6

Table 2. Estimated seedfall per acre by year

Year	Spruce			Fir		
	Total number	Germination[1]	Total viable	Total number	Germination[1]	Total viable
	Thousands	*Percent*	*Thousands*	*Thousands*	*Percent*	*Thousands*
1961	829	12	99	128	2	3
1962	55	16	9	1,385	41	568
1963	1,164	29	338	214	2	4
1964	835	61	509	421	7	29

[1] From germination tests made by the Seed Testing Laboratory, Massachusetts Agricultural Experiment Station, Amherst, Mass.

larger plots, and unbaited pitfall traps probably should be used for trapping within the plots. Natural seedfall also might be excluded, and the plots could be sown with known quantities of seed in amounts comparable to natural seedfall.

The plots protected against birds had more spruce germinants for 3 of the 4 years than unprotected ones (table 3). This might imply that birds appreciably reduced the numbers of seeds on the uncovered plots, but we don't believe this happened.

Although at least six species of seed-eating birds were present on the area after seedfall, we found no evidence that they fed on the seeds. Neither the birds nor their droppings were ever seen within the ½-milacre plots.

The wire exclosures protecting treatments II and III from birds also prevented hardwood leaves from falling within the plots (fig. 2). Numerous investigators have reported that such protection greatly enhances conifer germination and seedling survival. We are convinced that hardwood leaves were a major factor in accounting for the differences in numbers of germinants between plots with and without screen covers. Where leaves were excluded, there were nearly 4 times as many spruce germinants. However, such protection did not increase fir germination significantly.

Hardwood leaves did not appear to affect seedling survival.

Table 3. Number of germinants each year by treatment

Year	I		II		III		IV	
	Spruce	Fir	Spruce	Fir	Spruce	Fir	Spruce	Fir
1962	21	0	29	2	21	3	5	2
1963	1	89	7	107	5	253	2	164
1964	5	3	11	4	34	8	2	3
1965	9	13	30	10	34	4	1	5
Total[1]	36	105	77	123	94	268	10	174

[1] Analysis of variance of numbers of germinants transformed to $\sqrt{x + 1}$ and a comparison of means by Tukey's test showed significant differences at the 10-percent level between treatments III and IV, II and IV, and III and I for spruce. Fir differences were not significant at the 10-percent level.

We realize that the infrequency of observations could have caused some short-lived germinants to go undetected, thus affecting our survival data. However, we took special care in examining two open plots where the leaf litter was heaviest. Of the nine germinants found on these plots, only one failed to survive 4 years. This seedling succumbed, presumably from drought, in midsummer of the first year.

Our findings are in sharp contrast to those published by Davis and Hart.[3] They found mortality of first year germinants to be especially high on plots more than 25-percent covered by hardwood leaves.

Although we cannot definitely answer the question posed by the title at this time, our study has cast some doubt on the importance previously attached to mammal preferences for spruce rather than fir seeds. Further carefully designed studies will be needed to establish the true importance of this preferential feeding under natural conditions.

[3] Davis, Grant, and Arthur C. Hart. EFFECT OF SEEDBED PREPARATION ON NATURAL REPRODUCTION OF SPRUCE AND HEMLOCK UNDER DENSE SHADE. NE. Forest Exp. Sta., Sta. Paper 160, 12 pp., illus. Upper Darby, Pa. 1961.

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INVESTMENT ANALYSES

of Stand Improvement and Reforestation Opportunities in Appalachian Forests

by Owen W. Herrick
and J. Edwin Morse

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INVESTMENT ANALYSES

of Stand Improvement and Reforestation Opportunities in Appalachian Forests

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THE DECISIONS TO BE MADE

EFFECTIVE distribution of limited funds among many worthwhile activities is central in the planning and control of successful programs. And because administrators of forest-management programs must consider the need for timber-stand improvement and reforestation, criteria are needed for allocating available funds to the particular kind of projects that will yield greatest returns.

In a study carried out on the George Washington National Forest, 72 of the existing 143 site-stand condition classes were designated as candidates for timber-stand-improvement or conversion projects. But which projects are worth undertaking, and which should receive priority? These are decisions that confront program administrators and forest managers alike.

To help them in this we have made investment analyses of the 19 most prevalent (modal) project classes, which together encompass almost 124 thousand acres of this Forest in Virginia and West Virginia. By providing a basis for rating and comparing opportunities, these appraisals suggest what kinds of projects to favor in planning an efficient program for stand improvement and stand conversion.

STUDY APPROACH

At least two alternatives must be compared to evaluate a potential timber-stand-improvement or conversion opportunity. In this study we were concerned with expected rates of return on investment in stand treatment. Specifically, these rates reflect the difference between costs and returns for managing a timber stand under (1) a program with an initial investment in timber stand treatment followed by stand management that can include additional treatment investments as well as commercial timber cutting, and (2) a program in which the initial treatment is not made and any subsequent cutting is done exclusively by commercial timber sale.

Both stand-management programs include intermediate cutting to promote rapid growth but maintain adequate stand density to provide a fully stocked stand at maturity. These intermediate cuts are scheduled when at least 25 percent of the stand's basal area can be removed—provided, in the case of commercial cutting, this yields 2 thousand board feet of sawlogs or 5 cords of pulpwood per acre, the minimum net volume needed to be commercially operable.

Measuring Economic Desirability

The essential analytical concepts underlying investment analyses stress consistency and a standard method for evaluating stand-treatment opportunities as outlined by Marty et al. (*1966*). Our appraisals evaluate each project according to investment potential as measured by its internal rate of return. That is, the expected rates of return on investment in each stand-treatment project are based on value added by the project beyond that available from the untreated stand—in relation to the cost and length of time required to bring the stand to harvest.

Sequence of Evaluation

The sequence of evaluation includes choosing the project, estimating added yield, determining project cost, valuing additional yield, and computing rate of return. These steps concentrate attention upon the many factors (fig. 1) that play a part in defining project costs and returns.

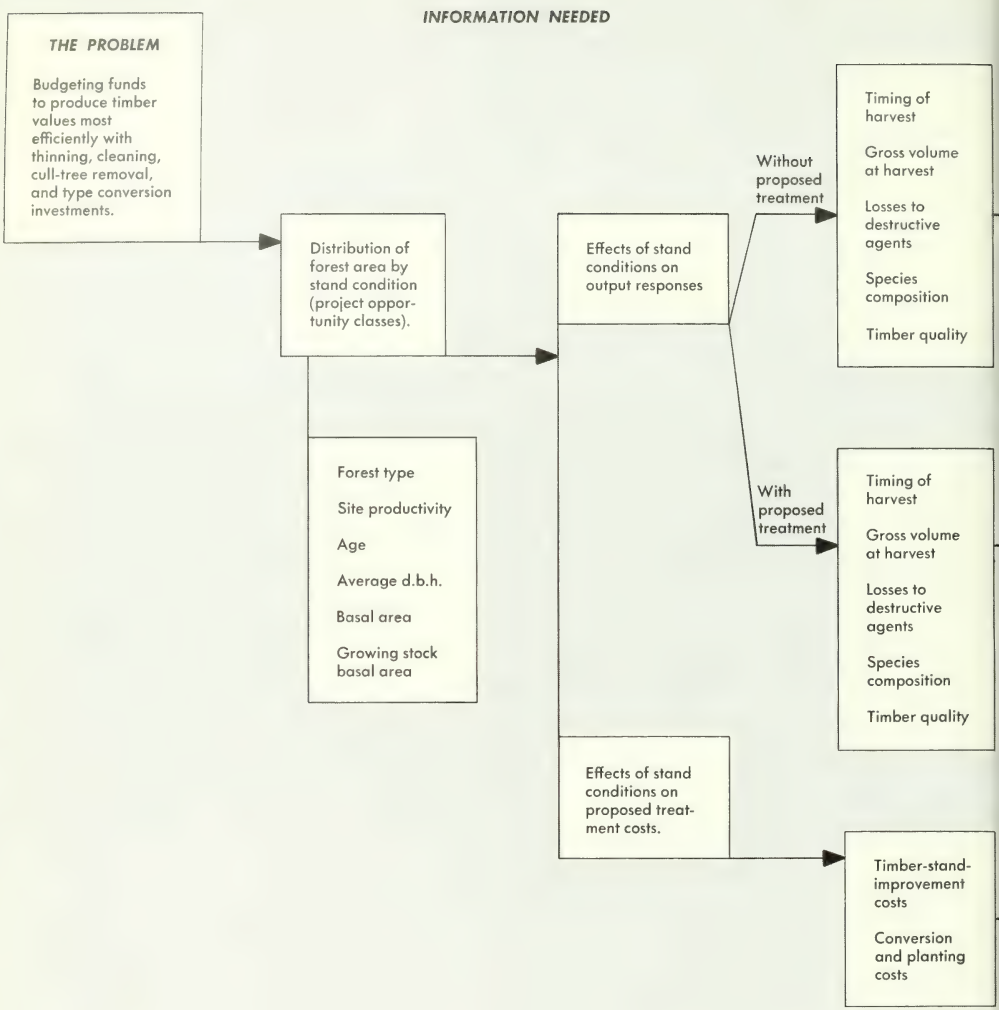
Timber stand conditions and the treatments, costs, markets, and prices used in these analyses are those experienced on the George Washington National Forest. The resulting rates of return apply directly to the most common project-investment opportunities found on this Forest. The results may extend to other properties under public forest management if similar conditions make this group of projects most important there also. However, projects omitted here because of their limited extent on the George Washington may provide higher rates of return than projects included in the analyses, and might be important elsewhere.

Project Selection

Site-stand conditions, together with their prescribed treatments, define project opportunities. By subdividing stand conditions into fairly homogeneous groups and choosing the most representative project opportunity from each group, we can make a single evaluation that can serve for a range of similar projects.

Project opportunities were selected for evaluation by choosing the "modal" or most frequently occurring conditions on the George Washington National Forest. Compartment examination and timber-inventory records provided a set of site-stand condition classes and an indication of the extent of each class. For each class a modal site-index and stand condition were determined, representing the most frequent situation within that class. Grouping of forest conditions involved six factors: forest type, site class, main-stand size class, age class, total basal area, and basal area in growing-stock trees. Three forest types were included in the study: conifer, oak, and cove hardwood. Three levels of site quality were used to subdivide each type. The four main-stand size classes used were seedling-and-sapling stands, pole stands, small sawtimber stands, and large sawtimber stands. Ten 20-year age classes and nine 20-square-foot basal-area classes formed the final classifications. Total basal area includes all four main-stand tree classes: desirable, acceptable, undesirable, and cull. Growing stock includes only desirable and acceptable trees.

Treatments tailored to modal conditions of each site-stand class were assigned on the basis of common practice, available management guides, and research information. In general, intermediate or improvement cuts are undertaken to increase timber yield (both volume and value) by reducing overstocked or fully stocked stands toward the lowest level of residual basal-area stocking that allows trees to fully utilize the site. The *Timber management guide for upland central hardwoods* (*Roach and Gingrich 1962*) identifies this basal area as the B-level of stocking, and the lower limit of stocking that is needed to reach the B level in 10 years on average sites as the C-level (fig. 2). A third stocking-guide level, B^1, was used to define the minimum total basal area that would allow intermediate cuts to include at


INFORMATION NEEDED
THE PROBLEM
Budgeting funds to produce timber values most efficiently with thinning, cleaning, cull-tree removal, and type conversion investments.
Distribution of forest area by stand condition (project opportunity classes).
Forest type
Site productivity
Age
Average d.b.h.
Basal area
Growing stock basal area
Effects of stand conditions on output responses
Without proposed treatment
Timing of harvest
Gross volume at harvest
Losses to destructive agents
Species composition
Timber quality
With proposed treatment
Timing of harvest
Gross volume at harvest
Losses to destructive agents
Species composition
Timber quality
Effects of stand conditions on proposed treatment costs.
Timber-stand-improvement costs
Conversion and planting costs

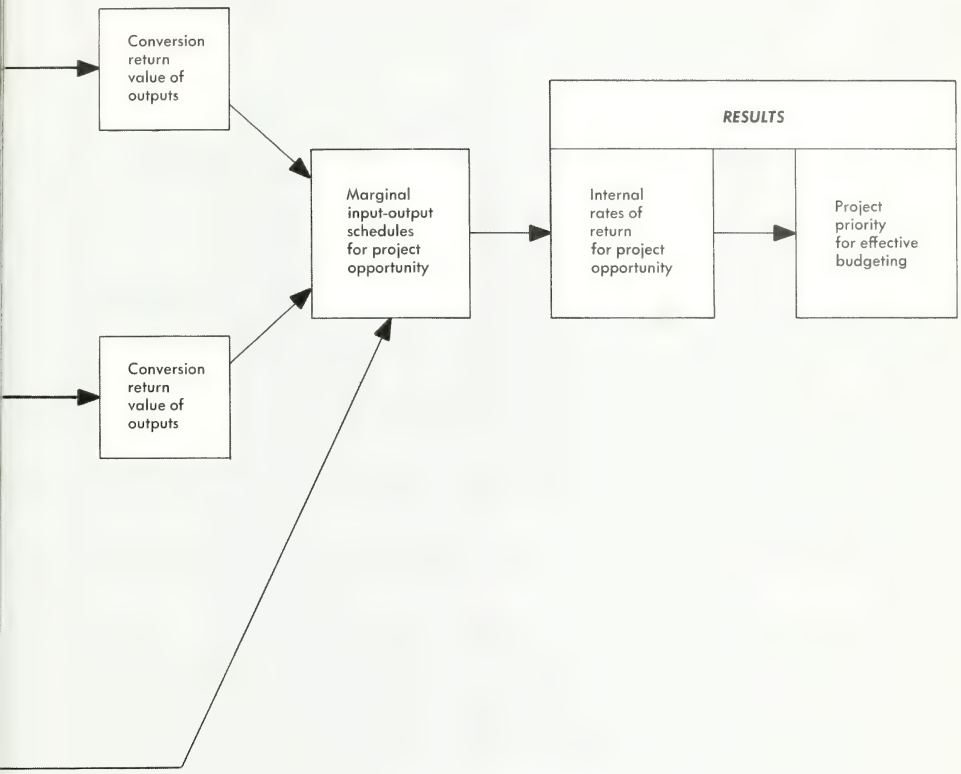

Conversion return value of outputs
Conversion return value of outputs
Marginal input-output schedules for project opportunity
RESULTS
Internal rates of return for project opportunity
Project priority for effective budgeting

Figure 1.—Steps in the analysis of opportunities for timber-stand improvement and restocking.

least 25 percent of the total basal area and still keep residual stocking at the B-level.

These stocking-guide levels provide a framework for identifying likely timber-stand-improvement or conversion opportunities. Stands with less than C-level of basal area per acre in growing-stock trees were considered for a type-conversion treatment. Those with a growing-stock basal area above C-level per acre but a total basal area less than B^1 per acre were to be retained but were considered to need no immediate treatment. Stands with growing-stock basal areas above C and total basal areas above B^1 per acre were considered to be candidates for a thinning treatment.

From the 72 site-stand condition classes identified by these criteria as candidates for treatment, 15 project opportunities involving the greatest acreage, plus 4 that represented younger age classes, were selected for evaluation. All selected projects fell in

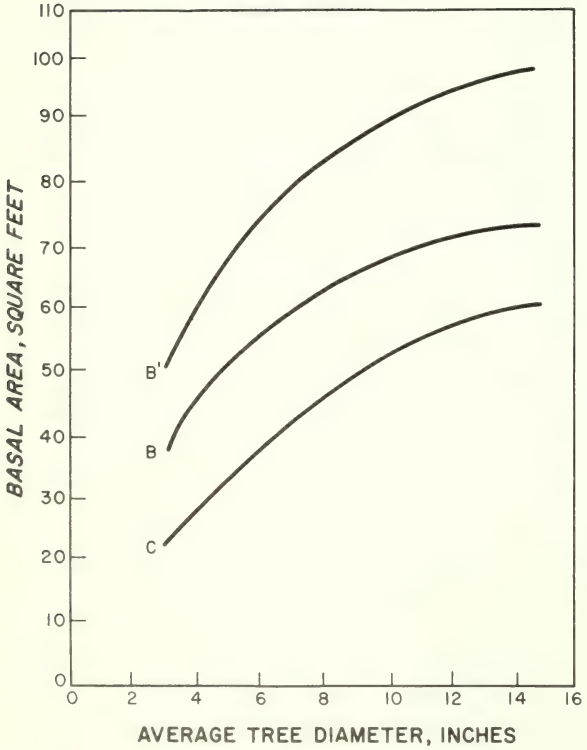


Figure 2. Upland hardwood basal area guides used for stand treatment prescription.

the oak forest type. In appendix B a complete description and schedule of costs and returns is given for each of these project opportunities.

RESULTS - - EVALUATING THE OPPORTUNITIES

We have used three cost and price levels to reflect low, average, and high job-difficulty in stand-treatment and timber-harvest activities; with market availability options for (1) both sawtimber and pulpwood, and (2) sawtimber only. Accordingly, under each market situation, the average and likely high and low limits for expected rates of return were computed for each project opportunity. This enables us to rank projects on the basis of their expected productivity so that those with the highest rates of return can be financed first. And those projects falling below some minimum level of economic desirability can be excluded from the competition for funds.

These evaluation procedures are discussed further later. But for those readers interested mainly in finding out how projects ranked and their relationships, the foregoing view of the evaluation process should suffice.

Results from these modal project analyses (table 1) show that immature timber stands on above-average sites would logically get priority for timber-stand-improvement funds; first in areas where only sawtimber markets are available, then where there are markets for both sawtimber and pulpwood. Having a pulpwood market for intermediate cuttings reduces the additional value to be gained by undertaking stand-improvement projects.

Where oak timber stands are more than 60 years old it is doubtful if expected rates of return are sufficient to justify stand-improvement projects. This is also the case for stands where high costs and low returns are anticipated because of stand conditions and location.

Furthermore, under current financial conditions, adequate rates of return for type-conversion projects on medium oak sites (site

Table 1.—Rates of return for project opportunity classes[1] according to market availability and cost-return options

Project opportunity class	Class definition (main stand)					Internal rates of return					
				Basal area		Sawtimber market only			Sawtimber and Pulpwood markets		
	Site index	Stand age	Average d.b.h.	Total	Growing-stock level[2]	Ave. cost, ave. return	Low cost, high return	High cost, low return	Ave. cost, ave. return	Low cost, high return	High cost, low return
	Feet	*Years*	*Inches*	*Sq. ft.*		%	%	%	%	%	%
A — Thinning	71+	41- 60	5.0-10.9	81-100	≥B	7.5	11.2	4.6	6.7	6.0	4.6
B — Thinning	51 - 70	41- 60	5.0-10.9	81-100	≥B	6.8	13.7	1.2	6.5	0.1	1.2
C — Thining & weeding	51 - 70	21- 40	5.0-10.9	101-120	≥B	4.5	7.9	0.5	3.2	4.4	0.5
D — Thinning	71+	21- 40	5.0-10.9	101-120	≥B	4.2	5.2	2.7	0	0	2.7
E — Thinning	51 - 70	41- 60	5.0-10.9	101-120	≥B	3.5	7.1	1.1	1.9	1.6	1.1
F — Thining & weeding	51 - 70	41- 60	1.0- 4.9	61- 80	≥B	3.4	5.8	0.9	3.5	6.2	0.9
G — Thinning	51 - 70	61- 80	5.0-10.9	101-120	≥B	2.3	3.7	0	2.4	3.5	0
H — Thinning	51 - 70	61- 80	5.0-10.9	81-100	≥B	1.2	0.6	1.7	1.6	0.4	1.7
I — Thining & weeding	51 - 70	21- 40	1.0- 4.9	81-100	≥B	0	7.1	2.1	0	7.0	2.1
J — Thinning	51 - 70	21- 40	5.0-10.9	121-140	≥B	0	0	0.3	0	0	0.3
K — Thinning	31 - 50	61- 80	5.0-10.9	81-100	≥B	0	3.0	0	0	1.4	0
L — Thinning	31 - 50	41- 60	5.0-10.9	81-100	≥B	0	1.0	0	0	0	0
M — Thining & weeding	31 -50	41- 60	1.0- 4.9	81-100	≥B	0	0	0	0	0	0
N — Conversion	51 - 70	101-120	11.0-16.9	101-120	<C	3.8	6.1	0	4.2	6.2	0
O — Conversion	51 - 70	121-140	11.0-16.9	81-100	<C	3.7	5.8	0	4.1	6.5	0
P — Conversion	51 - 70	41- 60	5.0-10.9	61- 80	<C	3.5	5.6	0	4.0	6.2	0
Q — Conversion	31 - 50	121-140	11.0-16.9	81-100	<C	0	2.8	0	0.3	2.8	0
R — Conversion	31 - 50	41- 60	5.0-10.9	81-100	<C	0	2.5	0	0.2	2.6	0
S — Conversion	31 - 50	101-120	11.0-16.9	121-140	<C	0	2.6	0	0.4	1.9	0

[1] See appendix for complete description of each project opportunity.
[2] Refers to stocking-guide levels in figure 2.

index 51–70) appear rather limited. These projects would probably be confined to low-cost—high-return situations, favoring locations where both sawtimber and pulpwood could be sold to minimize the initial cost of conversion. And unless nontimber benefits are important, projects to convert oak stands to pine probably would not be undertaken where oak site index is less than 50 feet. Investment analyses for these conversion opportunities indicate that the return on investment would be, at best, less than 3 percent.

DISCUSSION

Evaluations of modal project opportunities are intended to give expected rates of return on investment for each project considered. These rates of return then permit this group of projects to be ranked according to economic desirability. Therefore, consequent project ratings represent only the modal conditions of opportunities that were evaluated. They do not give adequate information for accurately predicting where other sets of stand conditions might fit into this group. However, we can rationalize why certain project opportunities apparently rank above or below others.

Interaction of Timber-Stand Characteristics

Timber-stand characteristics influence each project's cost, value added, and interval between investment and return. How they interact determines the project's economic desirability. And how well a project ranks according to economic desirability depends on what other combinations of timber-stand characteristics are represented in the in group of projects being evaluated.

A long period of time until harvest can minimize benefits from stand treatment done early in the rotation. Such extended timespans increase the probability that commercial timber sales alone will accomplish desired stocking, species composition, and grade structure changes in untreated stands. Also, where time between investment and return varies from one project to another, the value growth rate (rate of return) for equal treatment expendi-

tures will be less on a project requiring a longer period of time to accomplish similar changes in value.

When crop-tree diameter goals are used to determine rotation length, as in this study, the beginning modal diameter-class of a project opportunity influences the time period until final harvest. This means that, given similar project expenditures and changes in value, projects in stands with larger diameter trees yield a higher rate of return. Furthermore, if crop-trees on the more productive sites have larger diameter specifications for final harvest, the project investment interval might be longer than on projects on poorer sites. In such cases, despite the greater timber growth rate possible on a good site, a project on a medium site could yield a higher return to treatment because of its shorter period of investment.

Effect of Opportunity Costs

Some projects classified as low cost on the basis of invested funds might not be classed as low-cost projects if opportunity costs (income foregone in the untreated timber stand), are included with direct costs. Rates of return are usually highest for project opportunities in low-cost—high-return situations. However, exceptions occur if the opportunity cost, compared to value resulting from stand treatment, is proportionately greater in the low-cost—high-return option than in other cost-return options for the project. For example, under a high-cost—low-return combination an untreated timber stand might have insufficient value to justify a commercial timber-cutting operation. In this case the rate of return for a stand-improvement project simply reflects the treatment expenditure and return value of the treated stand—opportunity cost is zero. As a result, a high-cost—low-return combination can give the best rate of return for some projects.

On the other hand, anything tending to give the untreated timber stand greater value, such as having markets for pulpwood as well as sawtimber, usually increases the opportunity cost. Consequently, an investment in stand improvement normally has the greatest impact where intermediate removal of timber volume by sale of products, such as pulpwood, is not possible.

However, the effect of opportunity cost (income foregone) on stand-improvement projects differs from its effect on conversion projects. Both types of projects generally face higher opportunity costs where markets are available for other timber products in addition to sawtimber. But because these markets enable harvesting more of the hardwood stand they also reduce the initial treatment cost for conversion projects. Therefore, despite the higher opportunity cost, investments in timber-stand conversion usually earn a better rate of return where both sawtimber and other timber products can be sold.

It should be noted that several major considerations underlie the evaluation of conversion opportunities:

- First, markets are assumed to be available for the pine sawtimber and pulpwood produced on the areas converted from hardwoods.
- Next, present stand conditions are assumed to be representative of what the area produces as a hardwood stand without additional investment.
- Finally, rates of return for conversion opportunities are considered to be measured at maximum levels because the cost and values expected from conversion to pine are compared with values expected from the understocked hardwood stand.

The resulting rates of return are partial analyses for type-conversion projects. They can be used to guide policy decisions to convert poor oak site areas to pine rather than have them recur as less productive hardwood stands. But conversion rates of return alone do not necessarily indicate the optimum investment for an area—for this purpose they must be weighed against other alternatives such as investing to establish a productive hardwood stand on the area.

Limitations of Return-Rate Estimates

Obviously the reliability of return-rate estimates involves the relative strengths and weaknesses of the data used to determine them. Cost data, output-response data, and dollar prices for converting output responses to a common basis will not always be

exactly correct or unaffected by time. Thus the rate-of-return estimates for modal projects are not likely to be exactly correct—although they accurately establish relative priority among projects.

Long-term studies will eventually provide better and more complete information for accurate prediction of output responses. Until then decision-making must rely on the best evidence available at the time.

Moreover, product prices and processing costs may change in time; and differential price and cost changes could have a direct effect on comparisons among projects. That is, if harvesting and processing efficiency or product demand change more rapidly for some kinds of timber than for others, then projects yielding more of the favored timber than other projects would have a greater change in value of additional yield relative to present prices. But again, decision-making must be based on current prices until more reliable projections of future prices are available.

Finally, return-rate estimates for modal projects are based on dollar costs and returns of timber production. In this respect they measure only the net effect of tangible costs and returns to projects. For some projects, however, intangible or unmeasurable aspects can have important and even overriding influence on their desirability. For example, timber-stand improvement or conversion may occasionally cause gains or losses to wildlife habitat, watershed, and scenic values in the area being treated. However, judging the effect of these intangibles on specific projects is left to those who apply the modal project evaluations.

PROCEDURES UNDERLYING THESE ANALYSES

Estimating Yield

The first task in estimating value gained by stand treatment is to determine anticipated timber yields. Timber yields for the modal stands were projected both with and without prescribed treatment from the initial stand conditions to the final harvest. To determine when stand projections attained rotation age, the

following guideline relating crop-tree diameter goals to site quality for the oak forest type was used:

Site-index class (feet)	*Rotation d.b.h. class* (inches)*
40	14
60	20
80	26

*Weighted by species composition.

The projection of stand volume was done in terms of basal area, using a 10-year growth and inspection cycle. Stands were projected over each 10-year period at normal growth rates estimated to be the result of intensive management. These growth rates were developed with a modification of Meyer's *(1937)* method for estimating normal mortality and gross yield, using the following normal yield tables: Schnur *(1937)* for hardwoods, and Schumacher and Coile *(1960)* or Frothingham *(1914)* for pine. In addition, if stand treatment or commercial thinning reduced stocking down to B-level all normal mortality was considered "pre-harvested" for the next growth period, and was added to the period's normal growth rate to estimate gross response. When stands contained more than B-level basal area, they were projected at normal growth rates but the addition of normal mortality was reduced in proportion to the position of their stocking between B-level and normal stocking.

Basal area removals indicated in these stand projections were converted to gross volumes per acre by applying volume/basal-area ratios for each stand's average d.b.h. and merchantable height at the time of scheduled cutting.

Next we obtained separate estimates for losses to insects, disease, and planting failures based on the judgment estimates of research foresters. Fire losses were estimated from the probability of having a killing fire during the rotation (*Webster 1960*). These loss estimates for each projected stand, together with cull estimates based on the stand's timber merchantability and soundness classification projected from inventory data, were deducted from gross volumes to get estimates of net volume output.

Species composition.—Initial species composition for the modal

stands was obtained from George Washington National Forest timber-inventory data. These data give species by percent of net cubic-foot volume per acre for growing-stock trees 5.0 inches d.b.h. and larger. Species composition goals and the consequent changes required in modal stands to attain these goals were based on Forest Service timber-management guides (table 2).

The amount of change toward a species-composition goal for the final harvest was estimated by the relative amount of growing-stock basal area removed from the stand during intermediate cutting. For example, differences between the initial and desired species compositions shown in table 2 for oak forest type, site index 60 stands, amount to an overall change of 21 percent. Removing at least 21 percent of the growing-stock basal area, either in one cut or cumulatively, was considered sufficient to both remove undesirable species and cause subsequent growth to be distributed so as to fully attain the goal. Cutting, say, 10 percent of the growing-stock basal area would only achieve approximately

Table 2.—Initial and desired species composition by site index class, oak forest type, in percent[1]

Species or species group	Species composition for —					
	Site index 40		Site index 60		Site index 80	
	Initial[2]	Desired	Initial[2]	Desired	Initial[2]	Desired
Red oak	3	3	6	10	15	23
Black oak	9	9	13	20	19	19
White oak	4	4	13	20	16	24
Chestnut oak	49	50	33	25	26	18
Scarlet oak	14	7	12	9	11	5
Yellow poplar, basswood, cucumber tree	—	—	2	4	1	2
Sugar maple, black locust, black cherry	1	1	2	2	1	2
Red maple, black birch, beech	1	0	2	0	5	0
Hickory	3	0	7	0	1	0
Black gum	1	0	1	0	1	0
White pine	—	—	1	2	3	6
Yellow pine	15	26	8	8	1	1
Total	100	100	100	100	100	100

[1] Percent of net cubic-foot volume per acre of growing-stock trees 5.0 inches d.b.h. and larger.
[2] From George Washington National Forest, 1954-59 inventory.

half the desired change. The initial species composition of the stand was applied to yields from intermediate cutting.

Log-grade distribution.—Log-grade distribution for hardwood butt logs in the initial stand condition was also obtained from George Washington National Forest timber-inventory data. Butt-log grade distributions reported by Trimble *(1965)* were considered attainable at final harvest with an intensive hardwood management program. Both log-grade distribution tables appear in appendix A.

Changes in butt-log grade distribution were gaged according to the relative proportion of desirable versus acceptable growing-stock basal area in the stand initially and at rotation age. Removing all the acceptable basal area from the stand by intermediate cutting—that is, leaving only desirable basal area in the stand—produced a butt-log grade distribution as shown by Trimble *(1965)*. Removing less than the full amount of acceptable growing stock resulted in proportionately less of a move from the initial to the desired grade distribution.

Grade distribution for the entire tree was expanded from butt-log distribution on the basis of d.b.h. and merchantable height in logs by using information developed at the Fernow Experimental Forest.[1] As with species composition, butt-log distribution for the output of intermediate cutting was the same as in the initial stand condition.

Estimates of grade distribution in the sawtimber yield from stands converted to white pine were based on Forest-Survey data *(Ferguson 1964)* modified to include more recent log-grading experience. The following white pine grade distributions were used:

Type of cut	*Stand age (years)*	*Log grade*		
		1 (%)	*2 (%)*	*3 (%)*
Thinning	50	—	—	100
Thinning	60	—	50	50
Thinning	70	20	30	50
Harvest	80	25	35	40

[1]Unpublished data on file at Northeastern Forest Experiment Station, Upper Darby, Pa.

Options Evaluated

Because of the variety of locations and physical settings in which a project opportunity can occur, each has a range of possible situations for cost of treatment, market availability, unit value of output, and timber sales preparation cost. The following options were included in the analyses:

1. Project costs.—Typical costs per acre for the prescribed stand treatment and, in addition, likely high and low levels of this cost are quantified for each project opportunity. Costs used were based on 1963 and 1964 operations. These costs were calculated for three levels of job difficulty. At each level we (1) used equations relating labor-time and chemical used to the sum of diameters of the trees treated; (2) added reconnaissance and transportation charges corresponding to the level of accessibility for getting men and materials to and from the projects; and (3) increased each field cost 15 percent to cover miscellaneous and overhead expenses. This provided three total treatment cost figures for each project.

No attempt was made to analyze the costs of different treatment techniques; rather, the three treatment cost levels for each project opportunity permit choosing one that would best reflect doing the job in a specific timber stand. Such factors as stand accessibility, steepness, and ground condition, as well as techniques, could determine which cost level should represent a particular stand.

2. Markets.—Market availability for hardwood species is divided into (1) sawtimber markets only, and (2) sawtimber and pulpwood markets. Further, under both categories markets are assumed to be available for pine pulpwood and pine sawtimber as well as for operable volumes of small hardwood sawtimber cut in intermediate treatments.

3. Timber values.—Timber yield is valued at the conversion-return level, using dollars per unit of output based on average sales value (fiscal-year 1962–64) by products, species, and where possible, by log grade. In addition, high and low conversion-return values were determined as influenced by corresponding low and high costs for harvesting and transporting forest products

Table 3.—Conversion-return values[1] for standing timber by species (group), product, and price level

Species or species-group	Log grade	Price level		
		Average	Low	High
	SAWTIMBER			
	Dollars per M board feet Int. 1/4-inch rule			
Red oak	1	74	53	107
	2	32	12	62
	3	4	(−14)	28
Black oak	1	48	30	71
	2	13	(−2)	32
	3	1	(−20)	21
White oak	1	85	69	104
	2	36	21	55
	3	9	(−7)	37
Chestnut oak	1	25	7	44
	2	5	(−12)	27
	3	3	(−20)	20
Scarlet oak	(*)	11	(−9)	31
Yellow-poplar, basswood, cucumber tree	1	70	50	90
	2	45	27	65
	3	31	13	60
Sugar maple, black cherry, black locust	(*)	26	(−6)	58
Red maple, black gum, black birch, beech, hickory	(*)	4	(−13)	30
Yellow pine	(*)	13	(−10)	38
White pine	(*)	19	(−4)	43
	1	38	—	88
	2	20	—	46
	3	10	—	23
	PULPWOOD			
	Dollars per cord			
Hardwood	—	0.60	(−3.10)	5.60
Pine	—	3.20	(−0.30)	7.50

[1] These values include the addition to income for both the stumpage producer and processor, and the increase of permanent asset value (system development roads) on the George Washington National Forest, fiscal-year 1962-64.

* Ungraded.

(table 3). Separate timber-yield values were computed for each of these price levels.

Table 3 includes a number of negative conversion returns. Since timber volume projections would be affected if trees with a negative value are not felled, these negatives were subtracted from the positives to get stand yield values for intermediate cuts.

These conversion-return values are appropriate for public programs because they approximate the total increase in income to the economy from harvest of public timber *(Marty and Mott 1964, p. 22; Marty 1966, p. 12).* They include the addition to income for both the stumpage producer and processor, and the increase of permanent asset value (system development roads) on the National Forests.

Again as with treatment costs, selecting an appropriate price level for a specific timber stand depends upon the stand's location and physical characteristics.

4. Timber-sale preparation expenses.—The alternative timber-management programs (with treatment or untreated) result in different amounts of volume per acre to be harvested. It follows that costs per acre for timber-sale preparation will also differ. Timber marking and associated travel costs at $1.30, $2.20, and $0.65 per thousand board feet were used to compute corresponding average, high, and low timber-sale preparation costs for each timber sale's yield per acre.

Computing Rate of Return

The costs and added values for each modal project were used to compute the projects' rate of return. Income and expense schedules for each stand-management program were cast into a "marginal" schedule, which indicated the difference between the treated and untreated programs. Incomes in this schedule were those received in the treated-stand program beyond those available in the program without treatment, or any expenses in the untreated program that would be avoided in the treated program. Similarly, expenses in the marginal schedule were either those incurred in the treated program or incomes foregone in the untreated program (opportunity costs). The computer program

described in Marty et al. *(1966)* was used to measure the rate at which investment in each project grows towards the return it eventually generates, taking into account the amount and timing of costs and returns.

SUMMARY AND CONCLUSIONS

The system of analysis described here is designed to provide an investment-opportunity guide for timber-stand-improvement and conversion work on National Forests in the Appalachian Mountains. The project opportunities are for modal site-stand condition classes selected because of their importance on the George Washington National Forest. Low, average, and high cost and price options for each project are considered with markets available for both sawtimber and pulpwood, and for sawtimber only. The investment guide for each project is internal rate of return per acre resulting from treatment. Forest administrators can use these guides to rank the relative economic desirability of alternative project opportunities.

In terms of individual project-opportunity classes, the relative desirability of stand treatment varies according to the stands' physical aspects regarding accessibility and job difficulty, and its location with respect to timber-product markets. Timber-stand-improvement projects undertaken where markets are available for both pulpwood and sawtimber nearly always return less to treatment than the same project undertaken where only sawtimber can be sold. This is because intermediate cuttings for pulpwood give untreated stands greater value, which in effect narrows the benefit that stand treatment can achieve beyond that available without treatment.

With timber-type-conversion projects, however, pulpwood cutting is not so important for the added value it gives untreated stands, but rather for the reduction of initial treatment cost that results from being able to harvest more of the original timber stand. Consequently, in contrast to timber-stand-improvement projects, conversion projects nearly always return more to treat-

ment when undertaken where markets exist for both pulpwood and sawtimber.

Among the projects evaluated, priority for program funds would logically go to stand-improvement projects in immature timber stands on above-average (site index 71+) sites. Next follow projects on medium (site index 51–70) sites where, along with stand improvement in immature stands, a few worthwhile opportunities occur for type conversion in low-cost—high-return situations. Rates of return are generally inadequate to justify timber-stand-improvement projects for oak timber stands over 60 years old or in situations where high costs and low returns are anticipated. Similarly, unless non-timber benefits are important, type-conversion projects probably would not be undertaken where oak site index is less than 50 feet.

Timber-stand characteristics influence each project's cost, value added, and interval between investment and return. How they interact determines the project's economic desirability. And how well a project ranks according to economic desirability depends on what other combinations of timber-stand characteristics are represented in the group of projects being evaluated.

This group of projects or alternative courses of action are important to the managers of a National Forest. And the relative project priority can also apply elsewhere if similar conditions exist. The analyses are directed toward assisting the decision-maker—their main role should be to sharpen his intuition and judgment for making long-range planning decisions in timber-stand-improvement and stand-conversion programs.

■

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APPENDIX A

Table 4.—Current distribution of butt-logs in growing-stock trees in the oak type by species and 2-inch d.b.h. class[1]

(In percent)

D.b.h. class (inches)	Species or species group											
	Red oak, black oak			White oak			Chestnut oak			Yellow-poplar, basswood, cucumber tree		
	Butt-log grade			Butt-log grade			Butt-log grade			Butt-log grade		
	1	2	3	1	2	3	1	2	3	1	2	3
12	—	—	100	—	—	100	—	—	100	—	—	100
14	—	25	75	—	30	70	—	14	86	—	34	66
16	—	40	60	4	40	56	2	25	73	1	44	55
18	2	52	46	8	48	44	3	37	60	9	43	48
20	12	54	34	12	52	36	4	48	48	16	42	42
22	21	53	26	21	52	27	12	51	37	22	41	37
24	29	52	19	30	51	19	22	51	27	28	40	32
26	37	51	12	40	50	10	34	50	16	34	40	26

[1] From George Washington National Forest 1954-59 inventory.

Table 5.—Butt-log grade distribution considered attainable at final harvest through intensive management, by species and 2-inch d.b.h. class[1]

(In percent)

D.b.h. class (inches)	Species or species group											
	Red oak, black oak			White oak			Chestnut oak			Yellow-poplar, basswood, cucumbertree		
	Butt-log grade			Butt-log grade			Butt-log grade			Butt-log grade		
	1	2	3	1	2	3	1	2	3	1	2	3
12	—	—	100	—	—	100	—	—	100	—	—	100
14	—	24	76	—	40	60	—	62	38	—	45	55
16	19	17	64	21	39	40	60	22	18	17	51	32
18	34	13	53	38	31	31	67	18	15	45	33	22
20	54	16	30	52	23	25	75	13	12	66	20	14
22	72	17	11	62	19	19	81	9	10	80	10	10
24	86	12	2	71	14	15	86	6	8	90	4	6
26	96	4	—	81	10	9	91	3	6	97	0	3

[1] From Trimble 1965; U. S. Forest Service Res. Paper NE-31.

APPENDIX B

All projects discussed are for the oak timber type identified as having 50 percent or more of net cubic-foot volume in white, black, scarlet and chestnut oaks, with which hickory, yellow-poplar, yellow pine, white pine, and maples are commonly associated.

Each project is described below together with its schedule of costs and returns. The schedules identify (1) treatment cost, (2) timber value of the untreated stand (income foregone or opportunity cost as discussed here), (3) timber value resulting from the stand treatment (income), and (4) changes in timing of timber removal or rotation age caused by stand treatment.

For example, in the schedule for Project A under the average cost-return combination, treatment at stand age 50 costs $11.40 per acre. With markets for sawtimber only, income foregone from the untreated stand management program amounts to $17.15 at age 80 and $338.70 at age 120 for intermediate and final harvests per acre respectively, net of average costs for timber-sales preparation. The management program with stand treatment results in corresponding incomes of $10.90 at age 70 and $446.30 at age 100, indicating that treatment enables intermediate cutting 10-years sooner and shortens rotation length 20 years.

Under the high-cost — low-return column the schedule shows that only a final harvest is possible at these prices. And undertaking treatments at ages 50 and 70 shortens the rotation 20 years and triples income compared to the yield value for an untreated stand (both values minus high-level costs for timber-sales preparation).

PROJECT OPPORTUNITY A

Class title: Thinning well-stocked poletimber and small sawtimber stands on good sites.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	71+	80	Thinning and cull-tree deadening to remove 27 square feet of basal area per acre.
Age (years)	41-60	50	
Average d.b.h. (inches)	5.0-10.9	9.6	
Basal area (square feet)	81-100	93	
Growing stock basal area	$\geq$ B	88	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT A

Item	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Treatment	50	$ 11.40	$ 7.00	$ 17.50	$ 11.40	$ 7.00	$ 17.50
	70	—	—	15.05	—	—	15.05
Income foregone	60	—	—	—	.70	43.15	—
	80	17.15	92.75	—	16.40	70.85	—
	110	—	—	—	361.15	716.20	—
	120	338.70	706.90	82.75	—	—	82.75
Income:	70	10.90	58.05	—	10.90	58.10	—
	100	466.30	845.20	249.90	471.40	858.70	249.90

PROJECT OPPORTUNITY B

Class title: Thinning well-stocked poletimber stands on medium sites.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	51-70	60	Thinning and cull tree deadening to remove 26 square feet of basal area per acre.
Age (years)	41-60	50	
Average d.b.h. (inches)	5.0-10.9	8.0	
Basal area (square feet)	81-100	91	
Growing stock basal area	$\geq$ B	69	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT B

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Treatment	50	$ 8.60	$ 4.80	$ 14.20	$ 8.60	$ 4.80	$ 14.20
	60	—	—	—	1.10	28.00	—
Income foregone	100	16.80	67.85	—	31.10	78.25	—
	120	172.10	375.35	58.90	157.75	451.10	58.90
	70	10.90	53.75	—	10.90	53.75	—
Income:	100	211.65	470.65	—	213.09	483.45	—
	110	—	—	80.55	—	—	80.55

PROJECT OPPORTUNITY C

Class title: Thinning and weeding well-stocked poletimber and sapling stands on medium sites.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	51-70	60	Thinning, weeding, and cull tree deadening to remove 38 square feet of basal area per acre.
Age (years)	21-40	30	
Average d.b.h. (inches)	5.0-10.9	6.3	
Basal area (square feet)	101-120	105	
Growing stock basal area	$\geq$ B	77	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT C

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Treatment	30	$ 12.20	$ 7.25	$ 19.05	$ 12.20	$ 7.25	$ 19.05
Income foregone	40	—	—	—	1.25	31.30	—
	70	16.45	74.15	—	4.15	10.45	—
	100	—	—	—	156.35	417.70	—
	110	115.50	360.05	7.40	—	—	7.40
Income:	50	—	—	—	1.45	37.30	—
	60	11.35	58.30	—	—	—	—
	80	20.05	69.55	—	—	—	—
	90	179.15	389.20	31.15	202.20	449.05	31.15

PROJECT OPPORTUNITY D

Class title: Thinning well-stocked poletimber stands on good sites.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	71+	80	Thinning and cull tree deadening to remove 32 square feet of basal area per acre.
Age (years)	21-40	30	
Average d.b.h. (inches)	5.0-10.9	8.4	
Basal area (square feet)	101-120	109	
Growing stock basal area	$\geq$ B	105	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT D

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Treatment	30	$ 12.95	$ 8.15	$ 19.45	$ 12.95	$ 8.15	$ 19.45
	60	—	—	18.50	—	—	18.50
Income foregone	40	—	—	—	.65	45.25	—
	50	11.30	70.05	—	—	—	—
	60	—	—	—	14.10	60.60	—
	70	18.30	67.10	—	—	—	—
	90	—	—	—	41.80	125.85	—
	110	441.40	799.70	67.95	477.05	834.35	67.95
Income:	40	—	—	—	.70	35.70	—
	50	8.80	53.35	—	—	—	—
	60	—	—	—	13.10	57.25	—
	70	21.70	71.25	—	—	—	—
	80	—	—	—	35.80	106.65	—
	100	528.70	924.90	227.65	476.10	832.60	227.65

PROJECT OPPORTUNITY E

Class title: Thinning well-stocked poletimber stands on medium sites.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	51-70	60	Thinning and cull tree deadening to remove 35 square feet of basal area per acre.
Age (years)	41-60	50	
Average d.b.h. (inches)	5.0-10.9	8.0	
Basal area (square feet)	101-120	105	
Growing stock basal area	$\geq$ B	95	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT E

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Treatment	50	$ 15.70	$ 10.45	$ 22.65	$ 15.70	$ 10.45	$ 22.65
	60	—	—	—	1.50	47.85	—
	90	—	—	—	14.30	59.80	—
Income foregone	100	19.10	73.55	—	—	—	—
	110	—	—	—	175.60	382.65	—
	120	161.45	387.70	29.70	—	—	29.70
	80	14.80	62.75	—	14.80	62.75	—
Income:	100	—	—	84.65	—	—	84.65
	110	220.55	480.42	—	222.05	493.55	—

PROJECT OPPORTUNITY F

Class title: Thinning and weeding well-stocked poletimber and sapling stands on medium sites.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	51-70	60	Thinning, weeding and release to remove 27 square feet of basal area per acre.
Age (years)	41-60	50	
Average d.b.h. (inches)	1.0-4.9	2.9	
Basal area (square feet)	61-80	69	
Growing stock basal area	$\geq$ B	39	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT F

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Treatment	50	$ 16.15	$ 9.80	$ 24.70	$ 16.15	$ 9.80	$ 24.70
	100	9.70	5.65	15.45	—	—	15.45
Income foregone	130	57.75	187.05	—	59.70	221.00	—
Income:	100	—	—	—	1.20	32.85	—
	110	159.80	348.70	58.65	150.40	361.85	58.65

PROJECT OPPORTUNITY G

Class title: Thinning well-stocked poletimber and small sawtimber stands on medium sites.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	51-70	60	Thinning and cull tree deadening to remove 28 square feet of basal area per acre.
Age (years)	61-80	70	
Average d.b.h. (inches)	5.0-10.9	10.7	
Basal area (square feet)	101-120	102	
Growing stock basal area	$\geq$ B	86	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT G

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Treatment	70	$ 10.50	$ 6.35	$ 17.65	$ 10.50	$ 6.35	$ 17.65
Income foregone	80	16.85	59.45	—	16.85	58.45	—
	110	56.30	184.65	—	58.30	214.90	—
Income:	110	115.60	384.60	—	119.05	398.70	—

PROJECT OPPORTUNITY H

Class title: Thinning well-stocked poletimber and small sawtimber stands on medium sites.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	51-70	60	Thinning and cull tree deadening to remove 28 square feet of basal area per acre.
Age (years)	61-80	70	
Average d.b.h. (inches)	5.0-10.9	9.0	
Basal area (square feet)	81-100	88	
Growing stock basal area	$\geq$ B	84	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT H

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Treatment	70	$ 10.95	$ 6.65	$ 16.95	$ 10.95	$ 6.65	$ 16.95
	100	9.60	—	—	9.60	—	—
	90	—	—	—	1.60	40.05	—
Income foregone	100	16.65	70.85	—	—	—	—
	120	110.75	298.75	—	124.00	350.90	—
Income:	120	163.40	387.45	38.50	163.40	402.85	38.50

PROJECT OPPORTUNITY I

Class title: Thinning and weeding well-stocked sapling and poletimber stands on medium sites.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	51-70	60	Thinning, weeding, and cull tree deadening to remove 45 square feet of basal area per acre.
Age (years)	21-40	30	
Average d.b.h. (inches)	1.0-4.9	4.2	
Basal area (square feet)	81-100	97	
Growing stock basal area	$\geq$ B	62	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT I

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Treatment	30	$ 18.30	$ 11.85	$ 26.85	$ 18.30	$ 11.85	$ 26.85
	70	—	—	—	1.20	27.50	—
	80	9.30	48.30	—	—	—	—
Income foregone	100	—	—	—	20.00	78.75	—
	120	211.05	471.85	7.35	197.55	439.15	7.35
	60	12.65	66.05	—	12.65	66.05	—
Income:	80	15.70	67.90	—	15.70	67.90	—
	100	200.55	440.00	115.25	201.90	452.20	115.25

PROJECT OPPORTUNITY J

Class title: Thinning well-stocked poletimber on medium sites.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	51-70	60	Thinning and cull tree deadening to remove 50 square feet of basal area per acre.
Age (years)	21-40	30	
Average d.b.h. (inches)	5.0-10.9	8.8	
Basal area (square feet)	121-140	126	
Growing stock basal area	≥ B	82	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT J

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Treatment	30	$ 14.30	$ 9.30	$ 20.95	$ 14.30	$ 9.30	$ 20.95
	40	—	—	—	1.20	30.75	—
	50	12.05	51.65	—	—	—	—
	60	—	—	—	9.30	48.30	—
Income foregone	70	12.00	51.50	—	—	—	—
	80	—	—	—	18.15	68.30	—
	100	196.30	427.90	7.95	197.35	438.85	7.95
	40	—	—	—	1.35	30.80	—
	50	10.80	51.45	—	—	—	—
	60	—	—	—	12.00	51.50	—
Income:	70	17.95	67.15	—	—	—	—
	80	154.50	335.80	—	162.25	331.90	—
	90	—	—	31.80	—	—	31.80

PROJECT OPPORTUNITY K

Class title: Thinning well-stocked poletimber and small sawtimber stands on poor sites.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	31-50	40	Thinning and cull tree deadening to remove 20 square feet of basal area per acre.
Age (years)	61-80	70	
Average d.b.h. (inches)	5.0-10.9	10.4	
Basal area (square feet)	81-100	88	
Growing stock basal area	$\geq$ B	73	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT K

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Treatment	70	$ 9.80	$ 5.75	$ 15.60	$ 9.80	$ 5.75	$ 15.60
Income foregone	90	24.85	103.95	—	27.00	136.95	—
Income:	90	29.20	114.30	—	32.55	144.40	—

PROJECT OPPORTUNITY L

Class title: Thinning well-stocked poletimber and small sawtimber stands on poor sites.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	31-50	40	Thinning to remove 27 square feet of basal area per acre.
Age (years)	41-60	50	
Average d.b.h. (inches)	5.0-10.9	7.7	
Basal area (square feet)	81-100	88	
Growing stock basal area	$\geq$ B	88	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT L

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Treatment	50	$ 13.90	$ 9.00	$ 20.50	$ 13.90	$ 9.00	$ 20.50
Income foregone	60	—	—	—	1.84	28.00	—
	90	30.95	146.85	—	27.50	123.45	—
Income:	90	35.80	160.05	—	35.80	160.05	—

PROJECT OPPORTUNITY M

Class title: Thinning and weeding well-stocked sapling and poletimber stands on poor sites.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	31-50	40	Thinning, weeding, and cull tree deadening to remove 33 square feet of basal area per acre.
Age (years)	41-60	50	
Average d.b.h. (inches)	1.0-4.9	3.4	
Basal area (square feet)	81-100	83	
Growing stock basal area	$\geq$ B	77	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT M

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Treatment	50	$ 15.60	$ 9.55	$ 23.85	$ 15.60	$ 9.55	$ 23.85
Income foregone	120	38.80	184.30	—	38.95	186.55	—
Income:	100	—	—	—	25.35	142.35	—
	110	41.80	185.20	—	—	—	—

PROJECT OPPORTUNITY N

Class title: Converting poorly-stocked sawtimber and poletimber stands on medium oak sites to pine.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	51-70	60	Conversion to white pine by: (1) harvesting 8.9 cords and 3 M board feet/acre (net) if markets exist; (2) killing residual hardwoods > 5 inches d.b.h.; and (3) controlling saplings that interfere with planting and early survival.
Age (years)	101-120	110	
Average d.b.h. (inches)	11.0-16.9	14.0	
Basal area (square feet)	101-120	102*	
Growing stock basal area	< C	42	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT N

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Site preparation	0	$ 17.50	$ 12.20	$ 24.65	$ 4.50	$ 1.75	$ 9.05
Planting	0	34.00	26.00	40.00	34.00	26.00	40.00
Regeneration release	3	8.00	5.00	11.00	8.00	5.00	11.00
	5	8.00	5.00	11.00	8.00	5.00	11.00
Income foregone	80	22.00	70.20	—	23.70	110.65	—
	30	19.05	53.80	—	19.05	53.80	—
	40	21.40	60.25	—	21.40	60.25	—
	50	38.70	105.40	—	38.70	105.40	—
Income:	60	65.00	165.20	—	65.00	165.20	—
	70	77.05	189.00	—	77.05	189.00	—
	80	703.50	1,719.85	—	703.50	1,719.85	—

*Plus 9 square feet of undesirable saplings.

PROJECT OPPORTUNITY O

Class title: Converting poorly-stocked sawtimber and poletimber stands on medium oak sites to pine.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	51-70	60	Conversion to white pine by: (1) harvesting 16.4 cords/acre (net) if markets exist; (2) killing residual hardwoods > 5 inches d.b.h.; and (3) controlling saplings that interfere with planting and early survival.
Age (years)	121-140	130	
Average d.b.h. (inches)	11.0-16.9	11.8	
Basal area (square feet)	81-100	92*	
Growing stock basal area	< C	26	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT O

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Site preparation	0	$ 24.70	$ 17.80	$ 33.55	$ 6.55	$ 3.25	$ 11.80
Planting	0	34.00	26.00	40.00	34.00	26.00	40.00
Regeneration release	3	8.00	5.00	11.00	8.00	5.00	11.00
	5	8.00	5.00	11.00	8.00	5.00	11.00
Income foregone	80	—	—	—	2.40	60.75	—
Income:	30	19.05	53.80	—	19.05	53.80	—
	40	21.40	60.25	—	21.40	60.25	—
	50	38.70	105.40	—	38.70	105.40	—
	60	65.00	165.20	—	65.00	165.20	—
	70	77.05	180.00	—	77.05	189.00	—
	80	703.50	1,719.85	—	703.50	1,719.85	—

* Plus 18 square feet of undesirable saplings.

PROJECT OPPORTUNITY P

Class title: Converting poorly-stocked small sawtimber and poletimber stands on medium oak sites to pine.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	51-70	60	Conversion to white pine by: (1) harvesting 8.8 cords/acre (net) if markets exist; (2) killing residual hardwoods > 5 inches d.b.h.; and (3) controlling saplings that interfere with planting and early survival.
Age (years)	41-60	50	
Average d.b.h. (inches)	5.0-10.9	8.3	
Basal area (square feet)	61-80	78*	
Growing stock basal area	< C	35	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT P

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Site preparation	0	$ 34.55	$ 25.15	$ 46.04	$ 12.20	$ 7.25	$ 19.30
Planting	0	34.00	26.00	40.00	34.00	26.00	40.00
Regeneration release	3	8.00	5.00	11.00	8.00	5.00	11.00
	5	8.00	5.00	11.00	8.00	5.00	11.00
Income foregone	50	—	—	—	1.95	48.35	—
Income:	30	19.05	53.80	—	19.05	53.80	—
	40	21.40	60.25	—	21.40	60.25	—
	50	38.70	105.40	—	38.70	105.40	—
	60	65.00	165.20	—	65.00	165.20	—
	70	77.05	189.00	—	77.05	189.00	—
	80	703.50	1,719.85	—	703.50	1,719.85	—

* Plus 57 square feet of undesirable saplings.

PROJECT OPPORTUNITY Q

Class title: Converting poorly-stocked small sawtimber and poletimber stands on poor oak sites to pine.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	31-50	40	Conversion to hard pine by: (1) harvesting 14.2 cords/acre if markets exist; (2) killing residual hardwoods > 5 inches d.b.h.; (3) controlling saplings that interfere with planting and early survival.
Age (years)	121-140	130	
Average d.b.h. (inches)	11.0-16.9	15.9	
Basal area (square feet)	61-80	76*	
Growing stock basal area	< C	22	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT Q

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Site preparation	0	$ 18.30	$ 12.60	$ 25.90	$ 7.10	$ 3.60	$ 12.50
Planting	0	34.00	26.00	40.00	34.00	26.00	40.00
Regeneration release	3	8.00	5.00	11.00	8.00	5.00	11.00
Income foregone	60	—	—	—	2.20	34.65	—
Income:	40	12.55	35.65	—	12.55	35.65	—
	50	12.55	35.65	—	12.55	35.65	—
	60	33.15	99.75	—	30.15	99.75	—

* Plus 20 square feet of undesirable saplings.

PROJECT OPPORTUNITY R

Class title: Converting poorly-stocked poletimber and small sawtimber stands on poor oak sites to pine.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	31-50	40	Conversion to hard pine by: (1) harvesting 5.7 cords/acre (net) if markets exist; (2) killing residual hardwood > 5 inches d.b.h.; and (3) controlling saplings that interfere with planting and early survival.
Age (years)	41-60	50	
Average d.b.h. (inches)	5.0-10.9	6.7	
Basal area (square feet)	21-40	37*	
Growing stock basal area	< C	35	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT R

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Site preparation	0	$ 23.40	$ 16.30	$ 32.45	$ 10.50	$ 6.05	$ 17.02
Planting	0	34.00	26.00	40.00	34.00	26.00	40.00
Regeneration release	3	8.00	5.00	11.00	8.00	5.00	11.00
Income foregone	50	—	—	—	2.10	31.85	—
	40	12.55	35.65	—	12.55	35.65	—
Income:	50	12.55	35.65	—	12.55	35.65	—
	60	33.15	99.75	—	33.15	99.75	—

* Plus 46 square feet of undesirable saplings.

PROJECT OPPORTUNITY S

Class title: Converting poorly stocked small sawtimber and poletimber stands on poor oak sites to pine.

	Class definition	*Modal stand conditions*	*Prescribed initial treatment*
Site index (oak at 50 years)	31-50	40	Conversion to hard pine by: (1) harvesting 15.5 cords/acre (net) if market exists; (2) killing residual hardwoods > 5 inches d.b.h.; and (3) controlling saplings that interfere with planting and early survival.
Age (years)	101-120	110	
Average d.b.h. (inches)	11.0-16.9	11.3	
Basal area (square feet)	121-140	136	
Growing stock basal area	< C	40	

SCHEDULE OF COSTS AND RETURNS PER ACRE FOR PROJECT S

Income and cost items	Stand age (years)	Markets for sawtimber only			Markets for sawtimber and pulpwood		
		Average cost, average return	Low cost, high return	High cost, low return	Average cost, average return	Low cost, high return	High cost, low return
Cost:							
Site preparation	0	$ 21.35	$ 15.30	$ 29.10	$ 3.40	$ .95	$ 7.60
Planting	0	34.00	26.00	40.00	34.00	26.00	40.00
Regeneration release	3	8.00	5.00	11.00	8.00	5.00	11.00
Income foregone	60	—	—	—	2.75	43.05	—
Income:	40	12.55	35.65	—	12.55	35.65	—
	50	12.55	35.65	—	12.55	35.65	—
	60	33.15	99.75	—	33.15	99.75	—

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GROWTH response from THINNING young even-aged WHITE OAK stands

by Martin E. Dale

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GROWTH response from THINNING young even-aged WHITE OAK stands

THE OAKS rank among the most important hardwoods in this country. They furnish more native timber each year than any other related group of broad-leaved trees. In spite of their wide distribution and importance, we have little growth and yield information for managed oak stands to aid in selecting and scheduling silvicultural treatments.

In cooperation with various universities, state forestry organizations, and private industries, the U. S. Forest Service undertook a series of studies to estimate growth and yield of upland oaks for a range of stocking conditions.

The first studies were begun in 1950; 12 studies incorporating 228 permanent plots now extend over a large part of the upland oak range from Kentucky and Ohio west to Iowa and Missouri. These plots include varying conditions of stand age, species composition, and site quality. They ultimately will be used to develop yield tables for managed upland oaks, but some of the studies are too new to provide conclusive data at this time.

This interim report on two of these 12 studies covers the growth response from 25- to 35-year-old white oak stands on medium sites in southeastern Iowa and eastern Kentucky.

STUDY AREAS AND METHODS

The Iowa Stand

The natural white oak stand in Iowa, located on the Shimek State Forest, was 25 years old when first thinned in 1950. Twenty 1/5-acre plots were located in the stand; about half of them were on the east slope of one main ridge and the others were along the top and north slope of a second ridge. Site index, based on Schnur's 1937 curves, ranged from 55 to 69 and averaged 62.

In 1950, five different levels of stocking, each replicated four times, were created by thinning. Residual stands were left with 30, 40, 50, 60, and 74 square feet of basal area per acre in trees 2.6 inches d.b.h. or larger. Stems under 2.6 inches were not cut. Stem measurements made with a tape at breast height in 1953, 1955, 1958, 1960, and 1962 provide growth data for 12 years.

Before it was thinned, the stand averaged 84 square feet of basal area per acre, and 1,244 trees per acre larger than 0.6 inches diameter. This represents about 115-percent stocking (*Roach and Gingrich 1962, Gingrich 1964*).[1] In trees larger than 2.6 inches diameter, basal area was 77 square feet with 765 trees; this represented 95-percent stocking. Average diameter was 4.3 inches.

The Kentucky Stand

The natural white oak stand in Kentucky, located in Jackson County, was 33 years old when first thinned in 1962. Fifteen 1/2-acre plots were located in the stand adjacent to a small drainage. Site quality was higher than in Iowa. It averaged about 70 for oak and varied between 62 and 77.

Five levels of stocking, each replicated three times, were created by thinning. Residual stands were left with 15, 30, 45, 60, and 66 square feet of basal area in trees 2.6 inches d.b.h. and larger. Annual diameter measurements made with a tape on all trees over 2.6 inches d.b.h. provide growth data for 4 years.

[1] Stocking percent is used throughout this paper in place of the more familiar basal area because it expresses the same relative degree of stocking regardless of age or site.

Before it was thinned, the stand averaged 87 square feet of basal area and 1,761 stems per acre larger than 0.6 inches d.b.h. This represents about 125 percent stocking. In trees larger than 2.6 inches d.b.h., basal area was 76 square feet with 687 trees; this represented 96-percent stocking. Average diameter was 4.5 inches.

Comparison of Stands

In the main stand (trees larger than 2.6 inches d.b.h.) species composition, stocking, basal area, and number of trees were remarkably similar for the two study areas (appendix). But the Iowa stand was younger; average tree size was smaller; and the trees were shorter because site quality was lower. So cubic-foot volumes were somewhat lower in Iowa.

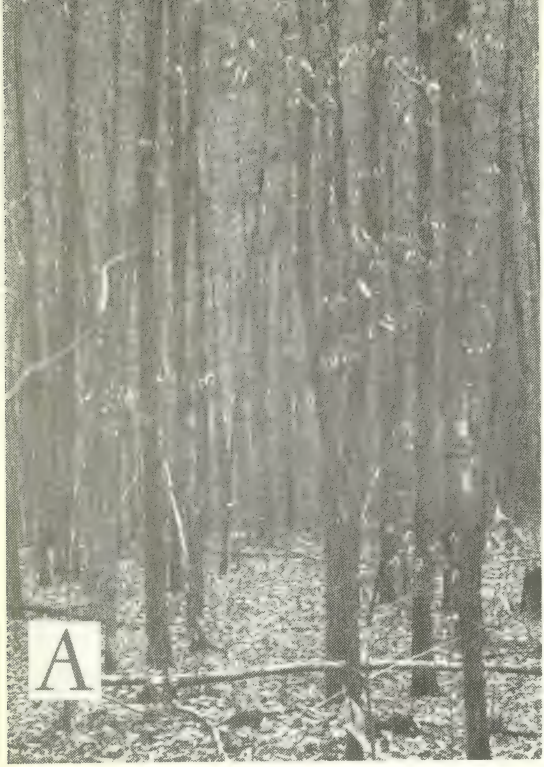
All plots were well stocked before treatment. Stockings in excess of 100 percent indicate that these stands were somewhat more dense than the average natural stand.

The two stands differed mainly in the understory trees (trees 0.6 to 2.5 inches d.b.h.). The understory in Kentucky contained about 1,074 stems per acre, compared with only 479 in Iowa. Red maple, dogwood, and sourwood—the most abundant species in the Kentucky stand—accounted for about 80 percent of the total. Hickory, the principal species in Iowa, accounted for about 55 percent of all understory stems there.

Thinning Method

We used a "free-thinning" system. Under this system, described by Braathe (*1957*), the marker is free to remove trees from all crown classes; the objective is to leave a suitable number of the best trees as evenly spaced as possible over the area.

In both Kentucky and Iowa, thinning was primarily to improve spacing around the better quality trees of the most desirable species (fig. 1), and thinning was much the same in both stands. However, two exceptions should be noted. The Kentucky stand had a few older residuals (an average of two or three per acre), and these were the first trees marked for cutting. Also, in Kentucky all stems less than 2.6 inches d.b.h. were cut in the lower



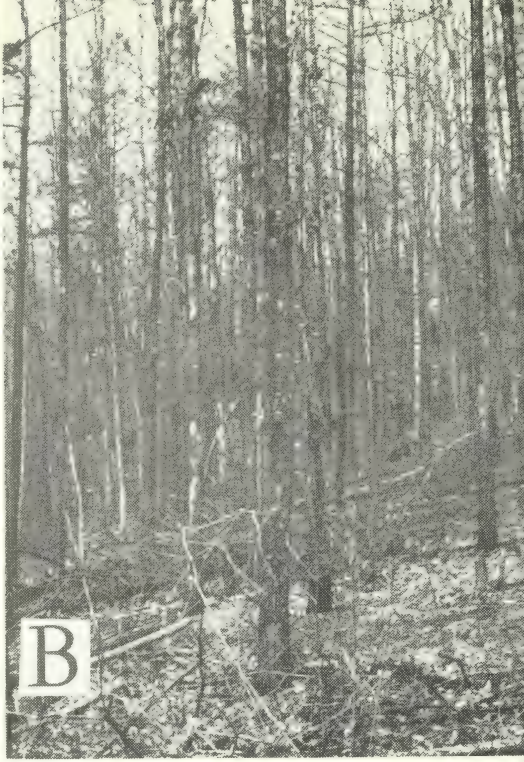
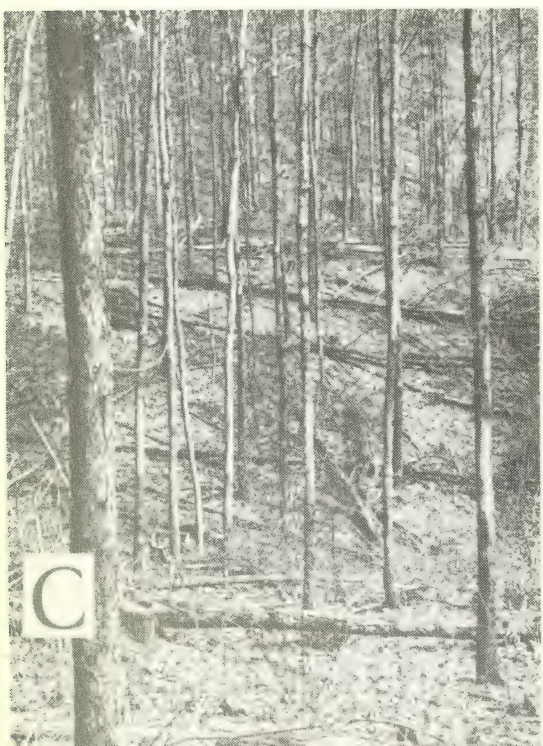
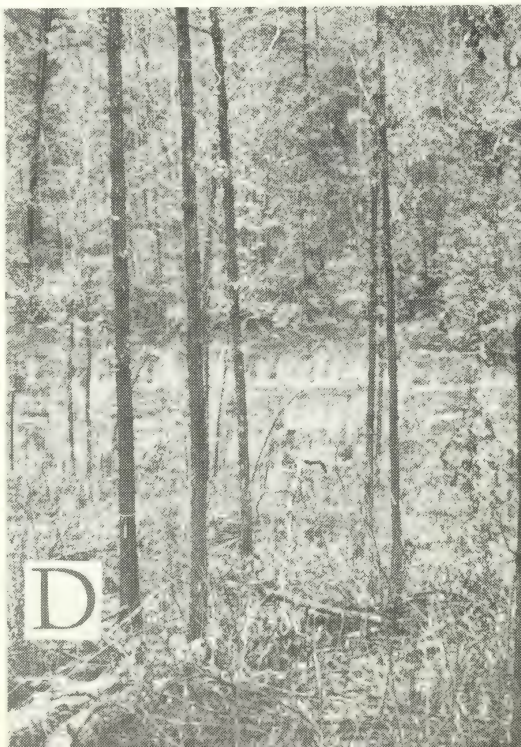


Figure 1.—The 33-year-old Kentucky white oak stand as it appeared 2 years after thinning. *A*, on unthinned plots; *B*, on plots with 50 percent residual stocking; *C*, on plots with 40 percent residual stocking; and *D*, on plots with 20 percent residual stocking.





three density classes, and none was cut in the two higher densities. In contrast, none of these smaller trees was cut in Iowa in any density class.

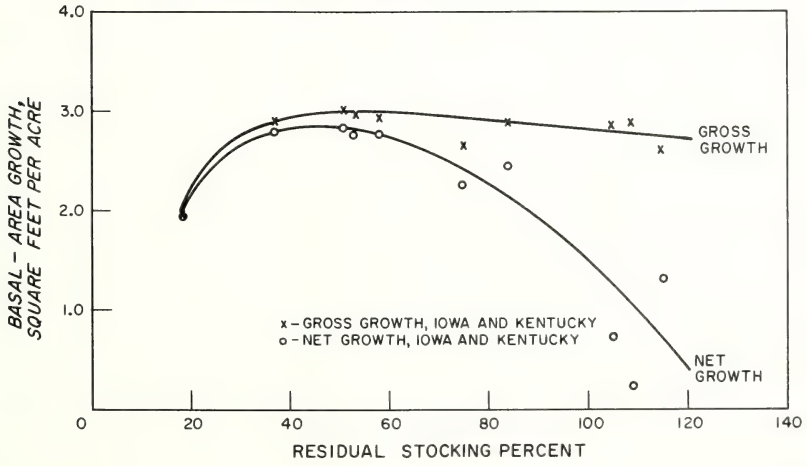
RESULTS

Basal-Area Growth

Basal-area growth was about the same in the Iowa and Kentucky stands for plots of similar residual stocking (tables 1 and 2). Likewise, the basal-area response in relation to stocking followed the same general pattern in the two stands (fig. 2). Growth response and total stocking in figure 2 are based on all trees 0.6 inches d.b.h. or greater occupying the area, so the curves probably describe the full growth potential for this particular age and site.

At densities between about 50- and 100-percent stocking, gross growth of these young oak stands averaged about 2.75 to 3.0 square feet of basal area per acre per year. This supports Moller's (*1954*) theory that the gross annual increment of intensively managed even-aged stands is substantially uniform for a fairly wide range of stand densities. However, gross basal-area growth seemed to drop slightly at maximum stocking; although this difference may not be statistically significant, a similar drop was noted by

Figure 2.—Relation between stocking percent and basal-area growth for young oak stands in Iowa and Kentucky.



Braathe (*1957*) for beech and Norway spruce stands in Europe.

This wide range of stocking for full site utilization means that foresters have considerable latitude to manipulate stocking and still achieve the full growth potential of an area. As long as enough trees are present to use all available growing space, stocking determines not how much wood is produced, but rather how it is distributed among the trees in the stand. Minimum stocking for full site utilization (about 50 percent) produces the same gross quantity of wood as maximum stocking, but the growth is on fewer trees. So individual trees grow faster in diameter, permitting shorter rotations.

Although gross basal-area growth was nearly constant from about 50-percent to maximum stocking, mortality caused the net growth within this range to vary. In both Iowa and Kentucky, net basal-area growth reached a maximum between 40- and 60-percent stocking. Below 40-percent stocking, net basal-area growth was reduced. Although individual trees grew faster, there were too few of them to occupy the site fully. Above 60-percent stocking, net growth was reduced also, because natural mortality increased. Mortality, represented in figure 2 as the difference between the gross-growth and net-growth curves, amounted to only 5 percent of gross growth at 50-percent stocking. Mortality increased with higher stocking and finally reached 75 percent or more at the higher densities. Net basal-area growth on plots that had little or no thinning was comparable to that reported by Schnur (*1937*). He reported a periodic increase of about 1.1 square feet for site 60 between ages 25 and 35 and about 0.8 square feet for site 70 between ages 30 and 40.

Mortality occurred mostly among the smaller trees, and even exceeded net growth in the lower diameter classes. Because these small trees are not merchantable and will never be needed as part of the final stand, they are generally disregarded by foresters when they examine net growth. Excluding these small 1- and 2-inch trees alters the form of the net-growth curve so that it does not drop off as sharply at the higher densities.

After two or three thinnings, we would expect all trees left in the stand to be merchantable. In that case, failure to thin will

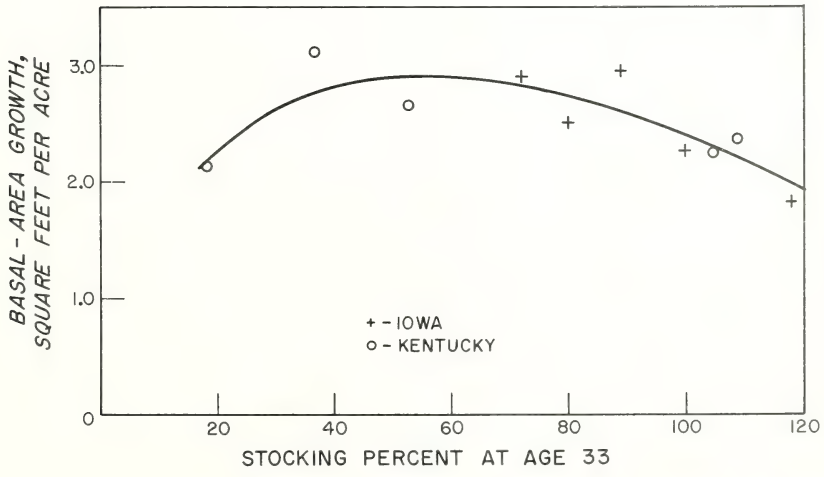
mean actual loss of products through natural mortality; and the more dense the stand is permitted to become, the greater the loss.

Because only the larger trees are very likely to become merchantable, net basal-area growth has been recalculated for those trees that reached at least 4.6 inches d.b.h. between ages 33 and 37. This new computation of the independent variable also limits the data to trees of similar age because it utilizes growth accrued only during the 4 years when the trees were between 33 and 37.

With this calculation, net growth dropped off at the highest densities much more gradually than before (fig. 3). This illustrates that most mortality losses were limited to the smaller trees. The new curve also shows that increases in net growth to be expected from thinning are less than indicated in figure 2. However, the increases in net growth between 60-percent stocking and 120-percent stocking are still substantial (about 2.9 versus 1.9 square feet per acre per year).

Although the highest density plots had about 100 more trees per acre (4.6 inches or more d.b.h.) than plots with 50-percent stocking, basal-area growth on these latter plots was approximately 50 percent greater.

Figure 3.—Relation between stocking percent and net basal-area growth of trees reaching 4.6 inches d.b.h. and larger between ages 33 and 37.

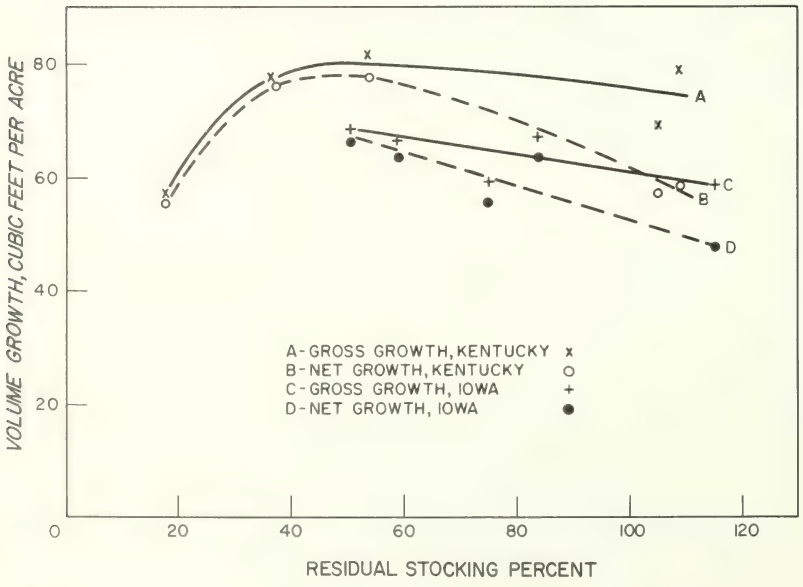


Cubic-Volume Growth

Gross cubic-volume production was relatively constant between about 50-percent stocking and maximum stocking for both stands (fig. 4). As with the gross basal-area curve, this again illustrates that the full productive capacity of the site is utilized with stocking of 50 percent or more. Cubic volume was computed using trees 2.6 inches d.b.h. and larger, and this may account for the slight drop in gross growth at the higher densities. If the 1- and 2-inch trees had been included in the the volume computations, gross growth probably would have remained even more constant.

Gross growth for plots with stocking greater than 50 percent ranged from 70 to 80 cubic feet per acre per year in Kentucky; in Iowa the range was 60 to 70 cubic feet per acre per year. With such a small sample, the volume difference between the two states may not be statistically significant, although it does agree with the well-established fact of greater volume production on the better sites. This relationship is found in all yield tables and is primarily due to greater height growth on the better sites.

Figure 4.—Relation between stocking percent and annual gross growth and net cubic volume growth in trees 2.6 inches d.b.h. and larger in Iowa and Kentucky.



Below 40-percent stocking, gross growth and net growth decreased similarly. Net growth also dropped as density increased. Near maximum stocking (110 percent), net growth was about 50 cubic feet per acre per year in Iowa and 57 cubic feet per acre per year in Kentucky, or about 75 to 80 percent of the gross. Comparable net growth reported by Schnur (*1937*) was about 54 cubic feet annually for site 60 between 25 to 35 years, and about 57 cubic feet for site 70 between 30 to 35 years.

The quantity of wood produced in these young oak stands is fairly constant from about 50-percent to maximum stocking. However, not all the wood produced is usable; and, unless these stands are thinned, about one-fifth to one-fourth of the annual volume production is lost through mortality. So, stands maintained at about 60-percent stocking should produce more, or at least as much, periodic net volume growth as stands at higher densities. Even more important, the volume growth will be placed on fewer trees that are, theoretically at least, higher in quality and value.

Cubic volumes in this report are based on local volume tables and no adjustment has been made to accommodate possible changes in stem form at the various stocking densities. Numerous investigators have shown that a heavy thinning regime tends to increase the rate of stem taper (*Newnham 1965, Meyers 1963, Braathe 1957, and Larson 1963*). So, cubic volumes shown for the lightly stocked plots may be overestimated and maximum net cubic-volume growth may actually occur at a slightly higher stocking percent than shown in figure 4.

Growth of Individual Trees

Growth per tree increased as stand density decreased (fig. 5). In other words, the fewer trees on an acre, the faster each grew in diameter. Diameter growth of white oak was slightly higher in Kentucky than in Iowa, especially at the higher stocking levels, but otherwise trends were similar.

The greatest diameter increase was at the lowest density level (18-percent stocking); these trees grew almost twice as fast in diameter as those at maximum stocking. However, total growth per acre was reduced at this low stocking because there were too

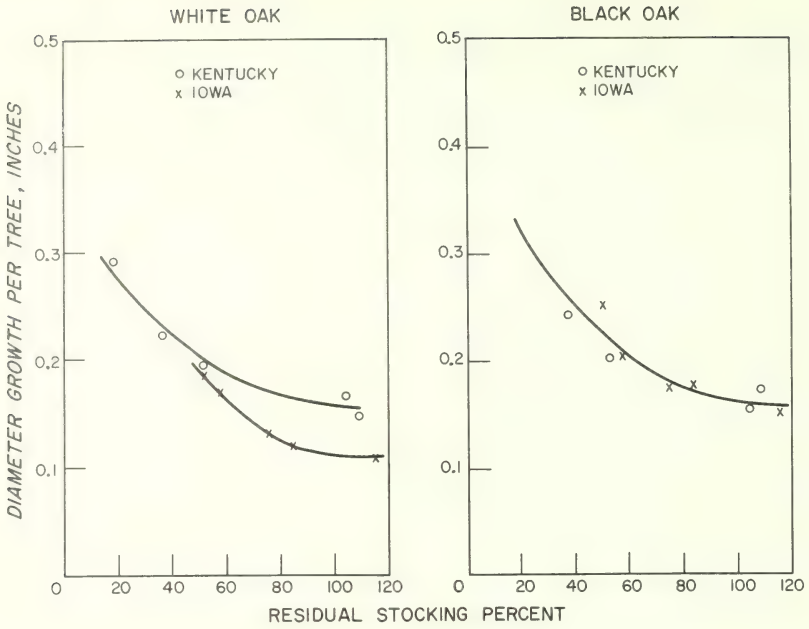


Figure 5.—Periodic annual diameter growth of the largest 100 trees per acre in relation to stocking percent.

few trees to utilize the site fully. Annual diameter-growth rate of white oak at 50-percent stocking was about 0.08 inches more than at maximum stocking in Iowa, and about 0.05 inches more for Kentucky—an increase of about 70 percent and 35 percent respectively.

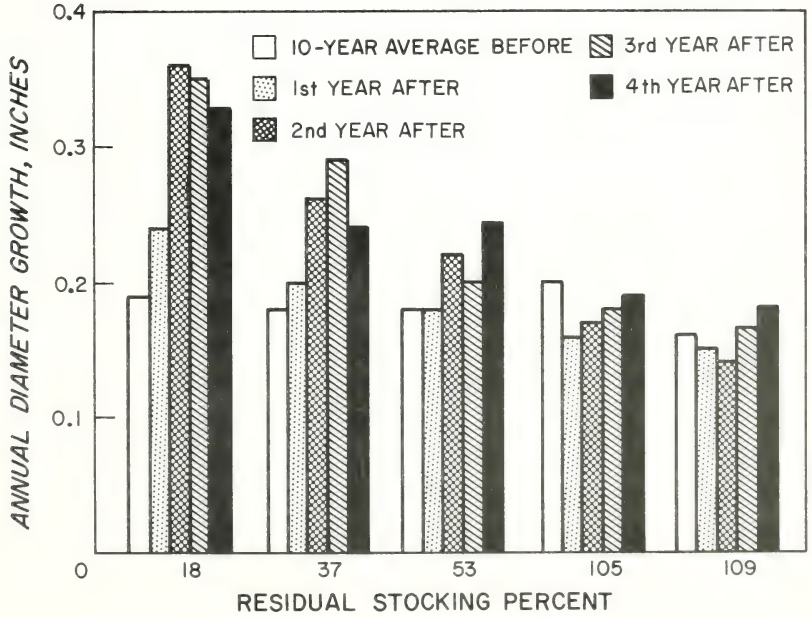
The black oak group, which included a few northern red oaks, grew faster in diameter than white oak for any given stocking level. Similar differences in growth rate of oak species were reported in West Virginia (*Trimble 1960*). Thirty-five percent of the 100 largest trees per acre were black oak in Iowa and only 20 percent in Kentucky. Black oak grew at about the same rate in Iowa and Kentucky.

Evidently white oak trees respond quickly to release. Minckler (*1957*) found that pole-sized white oaks in Illinois grew 41 percent faster the first year after release and that a similar increase over the first year's growth occurred the second year. Our study

in Kentucky indicates that most of the growth response was achieved by the second year and that this increased growth has been maintained through the third and fourth years (fig. 6). Annual variations in weather conditions will, of course, cause fluctuations from the average. With no thinning, or a very light thinning, growth was about the same as the 10-year average before thinning.

Differences in growth rate among species may explain some of the variation in basal-area or cubic-volume growth found among plots. For example, a predominately black oak stand would be expected to grow faster than a white oak stand. Nelson (*1964*) presented a theoretical model for adjusting growth when species mixture varies. Because this is an interim report pending accumulation of data from a longer growth period, this adjustment was not deemed worthwhile.

Figure 6.—Annual diameter growth for different stocking levels each year since thinning the 33-year-old white oak stands in Kentucky.



Effect of Stocking on Tree Quality

Thinning affects quality of trees in a stand as well as their growth. Average stand quality tends to improve when cull, defective, and inferior trees are removed; but this improvement may be offset if the thinning stimulates epicormic branching of the residuals. Four years after thinning the Iowa plots, Brinkman (*1955*) reported that for trees in the main crown canopy epicormic branches were fewer for (1) dominant trees, (2) single stems as compared with multiple-stem clumps, and (3) rather heavily-stocked stands. On trees bordering a clearcut forest opening in West Viriginia, epicormic branching was more prevalent on white oaks than on eight other species (*Northeastern Forest Experiment Station 1966*). Generally, these branches are more prevalent on trees of lower crown class and on the upper stems (*Smith 1965, and Brinkman 1955*).

In both Kentucky and Iowa stands we observed that white oak, when thinned to the lower densities, is subject to severe epicormic branching. Quality losses will undoubtedly more than offset any gains from increased volume when stocking is reduced below about 50 percent (fig. 7).

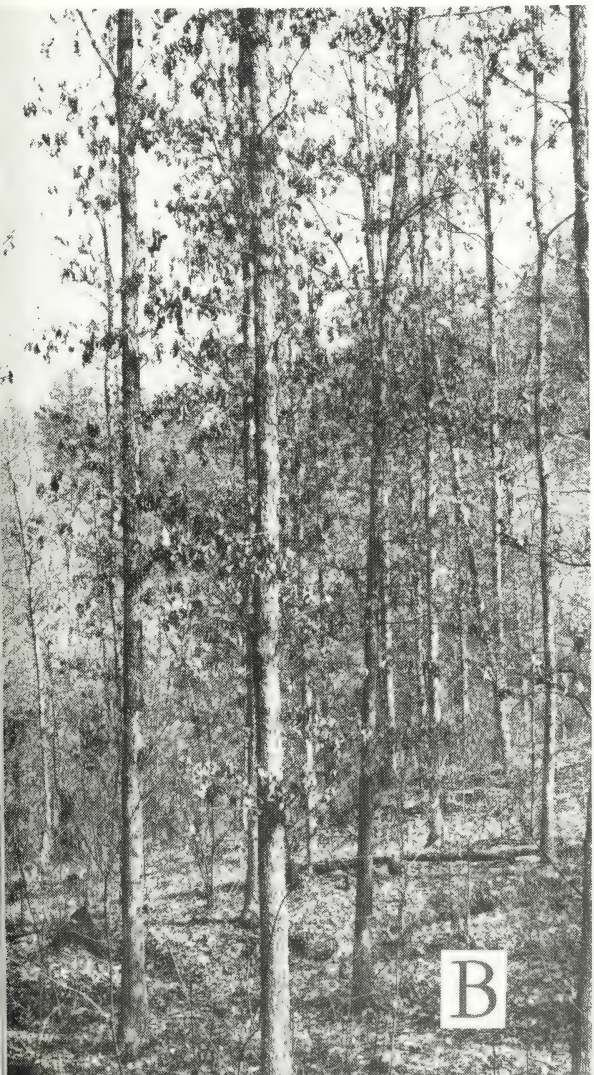


Figure 7.—*A*, white oak stand in Kentucky after being thinned to about 38 percent stocking (30 square feet of basal area per acre). *B*, note epicormic branch development 5 years later.

CONCLUSIONS AND RECOMMENDATIONS

Gross wood growth of 25- to 35-year-old white oak stands expressed either as basal area or cubic volume is nearly independent of stand density within the range from about 50 percent to maximum stocking. Net growth or yield is very likely to be greatest at about 50-percent stocking (45 square feet of basal area) because natural mortality increases rapidly at higher stand densities. If maximum stocking is maintained, 25 percent or more of the potential yield may be lost to mortality. Not only is net growth optimum at about 50-percent stocking, but individual trees grow faster in diameter, permitting shorter rotations.

Any stocking maintained much below 50 percent will not fully utilize the site. Although individual trees grow rapidly, there are too few of them to occupy the area fully. Losses in tree quality due to epicormic branching also become important at lower densities.

Based upon results from these two studies, and pending accumulation of additional data from stands thinned to very low densities, the following silvicultural treatment is recommended for similar young white oak stands managed for production of high-quality sawtimber.

Previously unmanaged fully stocked stands should be thinned to about 65 to 70 percent stocking (50 to 55 square feet of basal area) in trees over 0.6 inches d.b.h. This stocking is purposely somewhat higher than the studies indicate for maximum yields. Nevertheless it is heavy enough to eliminate much of the undesirable growing stock, stimulate growth of residual crop trees, and reduce mortality losses for 8 to 10 years. It is not so heavy as to cause a loss in volume production or profuse epicormic branching.

This first thinning should be primarily to improve growing conditions around the desirable crop trees. So, some of the cut must be in the main crown class, removing first the culls and overtopping wolf trees, then the lower value species, and finally some of the desirable species if necessary to achieve proper spacing and stocking. We cannot tell now whether the benefits justify the extra expense of cutting the poor intermediate and suppressed

trees in this first thinning. So at present these small trees probably should be left for later thinnings. Some may become merchantable, and meanwhile they serve as trainers and help reduce epicormic branching on crop trees.

A second thinning will be needed after 8 to 10 years. The second and subsequent thinnings may more safely reduce stocking to near the level for maximum volume production (50 to 60 percent stocking). By then crop trees will have a well-developed crown and will quickly utilize the additional growing space without as much risk of epicormic branching.

■

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Appendix

Table 1.—*Growth and yield of an oak stand in Iowa for 12 years after thinning at age 25*

Residual stocking percent	Basal-area growth[1]			Cubic-volume growth[2]		
	Net growth	Mortality	Gross growth	Net growth	Mortality	Gross growth
	— Square feet per acre per year —			*— Cubic feet per acre per year —*		
51	2.84	0.17	3.01	67.1	1.4	68.5
58	2.76	.17	2.93	64.0	3.0	67.0
75	2.25	.40	2.65	55.4	4.0	59.4
84	2.46	.42	2.88	63.9	3.8	67.7
115	1.31	1.35	2.66	48.0	10.4	58.4

[1] All trees 0.6 inches d.b.h. and larger.
[2] All trees 2.6 inches d.b.h. and larger.

Table 2.—*Growth and yield of an oak stand in Kentucky for 4 years after thinning at age 33*

Residual stocking percent	Basal-area growth[1]			Cubic-volume growth[2]		
	Net growth	Mortality	Gross growth	Net growth	Mortality	Gross growth
	— Square feet per acre per year —			*— Cubic feet per acre per year —*		
18	1.93	0.04	1.97	56.0	0.7	56.7
37	2.84	.07	2.91	76.0	1.2	77.2
53	2.76	.19	2.95	77.7	3.0	80.7
105	.72	2.12	2.84	57.2	12.0	69.2
109	.25	2.63	2.88	59.0	20.5	79.5

[1] All trees 0.6 inches d.b.h. and larger.
[2] All trees 2.6 inches d.b.h. and larger.

Table 3.—*Stand composition for young white oak stands in Iowa and Kentucky before thinning*

Section	Basal area	White oak	Other[1] oak	Hickory	Other[2]	Total
	Square feet per acre	*Trees per acre*				
			IOWA			
Understory	7	139	41	269	30	479
Main stand	77	505	177	60	23	765
Total	84	644	218	329	53	1,244
			KENTUCKY			
Understory	11	167	24	25	858	1,074
Main stand	76	462	118	28	79	687
Total	87	629	142	53	937	1,761

[1] In Iowa: Black, northern red and post oak.
In Kentucky: Black, scarlet and chestnut oak.

[2] In Iowa: Black walnut, American elm and ash.
In Kentucky: Red maple, dogwood, sourwood and black gum.

Table 4.—*Comparison of young oak stands in Iowa and Kentucky before and after thinning (all trees over 2.6 inches d.b.h.)*

Basal area		Stocking percent[1]		Number of trees		Cubic-foot volume[2]		Average d.b.h.	
Before	After	Before	After	Before	After	Before	After	Before	After
Square feet per acre		*Percent*		*Number*		*Cubic feet per acre*		*Inches*	
IOWA — AGE: 25 YEARS									
79	31	97	36	785	251	1,362	555	4.4	4.7
82	40	99	46	735	272	1,441	742	4.5	5.2
72	50	89	58	715	406	1,229	902	4.3	4.8
81	60	97	69	779	466	1,371	1,069	4.4	4.9
74	74	92	92	811	811	1,206	1,206	4.1	4.1
Average									
77	—	95	—	765	—	1,322	—	4.3	—
KENTUCKY — AGE: 33 YEARS									
75	15	97	18	634	125	1,646	310	4.6	4.7
76	32	93	37	700	257	1,587	650	4.5	4.8
73	45	94	53	680	409	1,558	895	4.4	4.5
79	60	100	75	690	653	1,705	1,172	4.6	4.1
75	66	98	81	732	716	1,556	1,288	4.3	4.1
Average									
76	—	96	—	687	—	1,610	—	4.5	—

[1] Based on tree-area-ratio, where tree area = $aN + b \Sigma D + c \Sigma D^2$ where a, b, and c are the regression constants; N is the number of trees per acre; ΣD is the sum of the individual diameters; and ΣD^2 is the sum of squares of the diameters. Regression constants used here are respectively: —.05066, .16977, and .03168 (Gingrich 1964).

[2] Cubic volume entire stem, based on formula: $V = 0.42$ BH, where B is the basal area and H is the total height. Height read from local height-d.b.h. curves. Constructed specifically for each stand from sample measurements.

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- The Iowa Conservation Commission, who kindly furnished land, labor, and supplies for installing the study.

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

LAND LEASING

An aid to developing outdoor recreation enterprises in Indiana, Kentucky, and Ohio

UNIVERSITY
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by James C. Whittaker

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LAND LEASING

An aid to developing outdoor recreation enterprises in Indiana, Kentucky, and Ohio

GETTING AROUND THE BARRIER

ONE BIG barrier to the development of private outdoor recreation facilities has been the capital investment needed for land. One way to get around this barrier is by leasing the land.

As part of its research efforts to help private woodland owners benefit from the recreation potential on their land, the U. S. Forest Service has made a study of land leasing for recreational purposes in Indiana, Kentucky, and Ohio. The results indicate that leasing has worked out well for most of those who have tried it.

The study was based on a questionnaire survey of 56 individuals and private organizations that lease privately owned land for outdoor recreation. Of the 56, 43 responded. The list of lessees was compiled in cooperation with the Soil Conservation Service.

RESULTS

Lessee Characteristics

The 43 lessees were grouped into five classes. Eleven were *hunting-shooting organizations;* they leased land for hunting and target shooting. Nine were *fishing-boating organizations;* they needed land to have access to lakes, ponds, and rivers. Eight were *group-family outing organizations;* they leased land for a variety of outdoor activities. Seven were *outdoor-sport organizations;* they wanted land for a single sport such as archery or golf. The other eight were *individuals or partnerships;* they leased land for a particular exclusive use or to provide recreation for others.

The 35 organizations reported 14,526 members, 84 percent of whom were members of the group-family outing organizations; 8 percent members of fishing-boating organizations; 5 percent hunting-shooting organizations; and 3 percent outdoor-sport organizations. The number of members in the various organizations ranged from 6 to 175 for hunting-fishing, 20 to 400 for fishing-boating, 50 to 4,200 for group-family outing, and 25 to 100 for outdoor-sport groups.

Area Owned or Leased, and Length of Lease

All together, the 43 lessees owned 1,617 acres and leased 16,972 acres of land, lakes, and ponds throughout the three States. Those from Ohio accounted for 61.6 percent of the leased acreage, those from Kentucky 25.4 percent, and those from Indiana 13.0 percent. Throughout the three States, more than half the leased acreage was forest-covered, over one-third was open land, and most of the rest was ponds or lakes (table 1).

The hunting-shooting organizations leased 35 to 5,000 acres (median 400). The fishing-boating organizations leased 2 to 960 acres (median 23). Group-family outing organizations leased 2

Table 1. — Leased area: percentage of acreage, by type of resource and location

Resource	Indiana	Kentucky	Ohio	All
Ponds or lakes	9.2	3.5	10.0	8.3
Forest-covered	46.4	55.6	55.9	54.6
Open land	44.4	40.9	29.1	34.1
Other[1]	—	(*)	5.0	3.0
Total	100	100	100	100

* Less than 0.1 percent.

[1] Brush-covered and swampy land.

to 3,000 acres (median 23). The outdoor-sport organizations leased 10 to 150 acres (median 50). And individuals and partnerships leased 20 to 300 acres (median 36).

More than half the acreage leased by hunting-shooting and boating-fishing organizations was forest-covered. Open land generally comprised most of acreage leased by other organizations, although a nearly equal amount of ponds and lakes was leased by group-family outing organizations. As would be expected, ponds and lakes accounted for the second greatest part of the acreage leased by fishing-boating organizations

The length of lease varied from 1 to 99 years for all acreage, the median period being 5 years. A lease length of 1 year was most frequently reported. Median length lease values varied from state to state and between specific land resources within states (table 2).

Table 2. — Typical length of lease found

(Median number of years)

Resource	Indiana	Kentucky	Ohio	All
Ponds or lakes	6.5	1.5	14.5	6.5
Forest-covered	7.5	3.0	5.5	5.0
Open land	7.5	5.0	10.0	5.0
Others	—	1.0	1.0	1.0
All resources	7.5	2.0	9.0	5.0

Lease length varied with type of organization. Hunting-shooting organizations leased resources from 1 to 20 years, 1 year being the median period. Fishing-boating organizations, on the other hand, leased resources from 1 to 99 years, with a median of 6.5 years. Length of lease varied from 1 to 99 years for group-family outing organizations, 1 to 10 years for outdoor-sport organizations, and 1 to 15 years for individual or partnership leases; all had a median period of 5 years.

Ten lessees reported that they had leased non-water resources to have access to a body of water. Only 4 of the 10 were classed as fishing-boating organizations. Eight of the 10 reported that they gained access to 400 to 3,000 feet of shoreline by such leases. A comparison of lease rates being paid by these 10 lessees with those being paid by all others indicated that they paid somewhat less per acre for forest-covered land and open land.

Rental Rates Paid

Lessees paid an average of $1.80 per acre for the resources they leased throughout the three States (table 3). Ponds and lakes were leased for the highest average rate ($4.87) and forest-covered land for the lowest ($0.51). There were some important differences between States.

Outdoor-sport organizations paid the highest average rates ($21.78 per acre), fishing-boating and group-family outing organizations the second highest ($2.38 per acre), individual or partnership lessees the third highest ($1.69 per acre), and hunting-shooting organizations the least ($0.53 per acre).

Table 3. — Average lease rate paid by all lessees for each type of resource in each State, weighted by acres leased

(Dollars per acre annually)

Resource	Indiana	Kentucky	Ohio	All
Ponds or lakes	3.92	13.17	3.84	4.87
Forest-covered	.32	1.23	.52	.51
Open land	.83	10.00	1.21	2.85
Other	—	25.00	2.93	3.02
Average: all resources	0.88	8.97	1.18	1.80

Structures such as buildings, boat docks, and storage barns were included in slightly more than one-fifth of the leases reported. Their influence upon the lease rates being paid was generally negligible. Where some portion of the lease rate was attributed to structures, however, the figure used to derive an average rate for the resources involved was appropriately reduced.

How Lease Rates Were Determined

Over half the lessees indicated that the lease rate being paid was determined by the landowner asking what they deemed a reasonable rent (table 4). More than one-third indicated a reason other than one of the four choices on the questionnaire. Being able to lease for a non-monetary compensation or for a strictly nominal fee were among the other reasons most frequently given. It is interesting to note that outdoor-sport organizations, who

Table 4. — How lease rates were determined; number of each kind of lessee and reason for the rate

Reason	Kind of respondent					
	Hunting-shooting	Fishing-boating	Group-family outing	Out-door-sport	Individ-ual or part-nership	All re-spond-ents
A rate being paid by other persons or organizations for such use.	1	0	1	0	0	2
An amount equal to what the landowner could earn in some other use.	0	0	0	1	0	1
An amount derived by considering expected income and costs.	0	1	1	1	0	3
Landowner asked what seemed reasonable.	5	6	3	1	6	21
Other reasons: provided by member, provided for non-monetary remuneration, suggested by lessee, etc.	4	2	2	4	2	14
Total	10	9	7	7	8	41

paid the highest average rates, considered reasonable requests by the landowner less important than other lessees.

Reasons for Leasing

Besides asking how lease rates were determined, we asked lessees why they leased the resources they controlled. The pattern of responses to this question was much the same as that for the question about lease rates. Nearly half the lessees gave two reasons for leasing the resources presently controlled: a favorable location and a reasonable rate (fig. 1). Two other similar reasons were frequently chosen: already having adjacent land and being near a good road. Hence location characteristics influence individuals and organizations seeking land to lease for outdoor recreation.

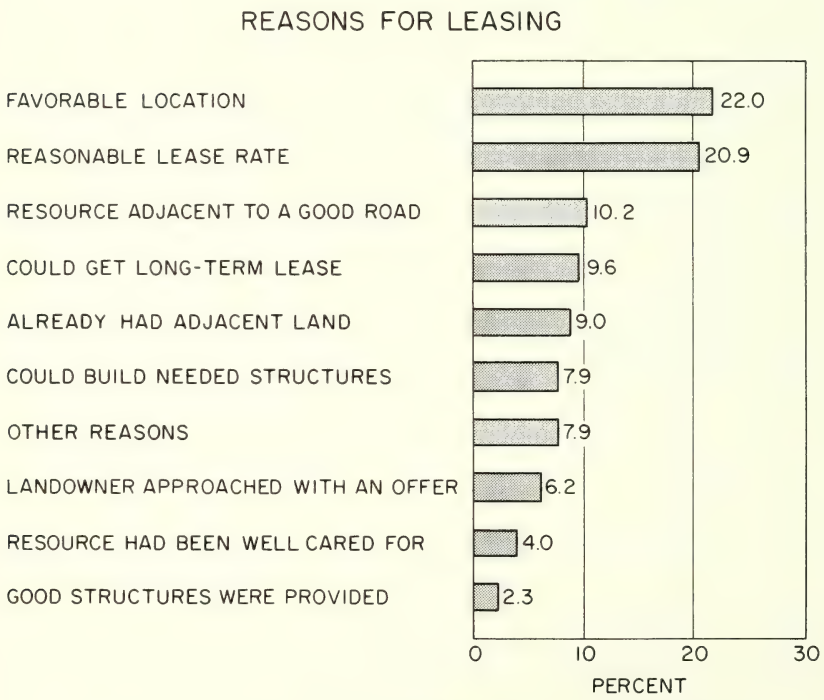


Figure 1. — Reasons for leasing land, by percentage. Lessees were encouraged to indicate more than one reason, and all 43 lessees made a total of 177 indications. The percentages were based on the total reasons that each category received.

Table 5. — Necessity of leased resources: number of times each kind of lessee indicated each necessity category[1]

	Absolutely unnecessary	Desirable but unnecessary	Generally necessary	Absolutely necessary
Hunting-shooting	3	2	7	8
Fishing-boating	0	4	4	4
Group-family outing	0	0	2	7
Outdoor-sport	0	2	2	5
Individual or partnership	0	1	9	3
All lessees	3	9	24	27

[1] Since each lessee could indicate a necessity category for each type of resource being leased, a total of 63 indications were made by the 43 respondents.

Relative Importance of Resources

Most lessees indicated that the resources they leased were necessary to meet their members' or users' needs (table 5). Overall, fewer than 5 percent indicated that any of the resources being leased was absolutely unnecessary for members' or users' satisfaction. Fishing-boating organizations reported that they had to lease land resources they really did not need more often than any of the other classes of respondents. However, hunting-shooting and outdoor-sport organizations ranked a close second and third, the former being the only group to indicate that any leased resources were absolutely unnecessary for members' satisfaction.

Use of Leased Resources

Of the 43 lessees, 29 reported 110,335 user-days[1] for all activities on land owned and leased in 1965. Boating, fishing, swimming, and water-skiing accounted for well over half the user-days reported (fig. 2). Camping, fishing, hunting, picknicking, and swimming were available at one or more of the sites leased by all but the outdoor-sport organizations (fig. 3 and fig. 4). Not every lessee made all five activities available, but taken all together, at least one in each category except the outdoor-sport group provided all five of them.

[1] As used here, 1 user-day equals 1 person using 1 facility part of or an entire day.

An indication of how much the four kinds of organizations used their leased resources was obtained by calculating user-days per member during 1965 (based on responses from 25 organizations). Fishing-boating organizations averaged 59 user-days per member in 1965, 7 groups reporting. Hunting-shooting organizations ranked next with about 10 user-days per member, 7 groups reporting. Third were the outdoor-sport organizations

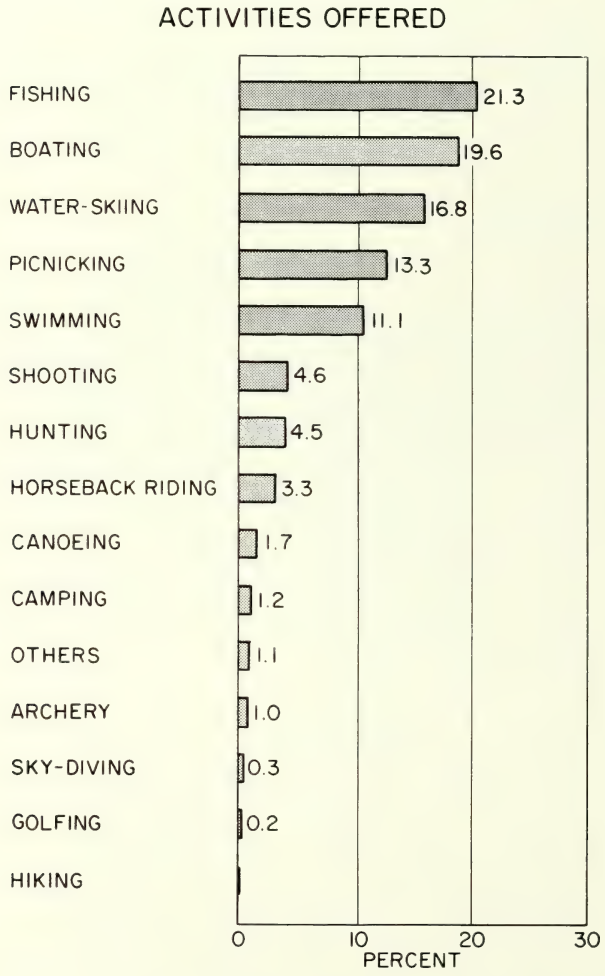
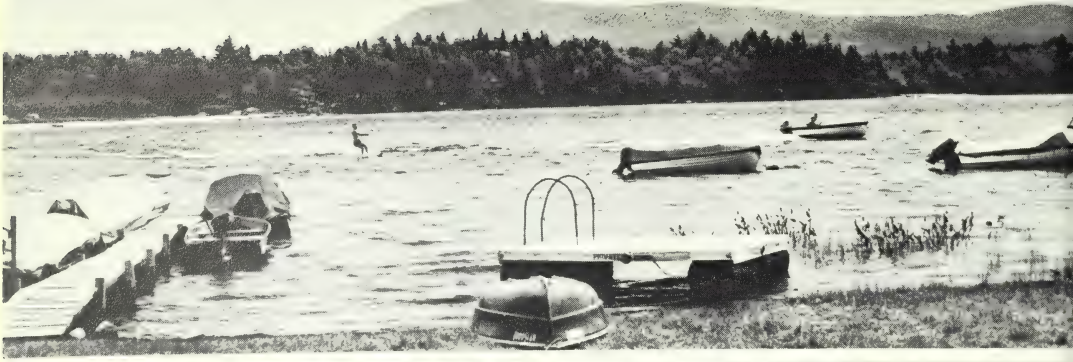


Figure 2. — Percentage of user-days in each category of activities, based on a total of 110,335 user-days reported by 29 lessees.

PHOTO CREDIT: OHIO CONSERVATION DEPARTMENT

Figure 3. — Leased lands are used for a wide variety of outdoor recreation activities.



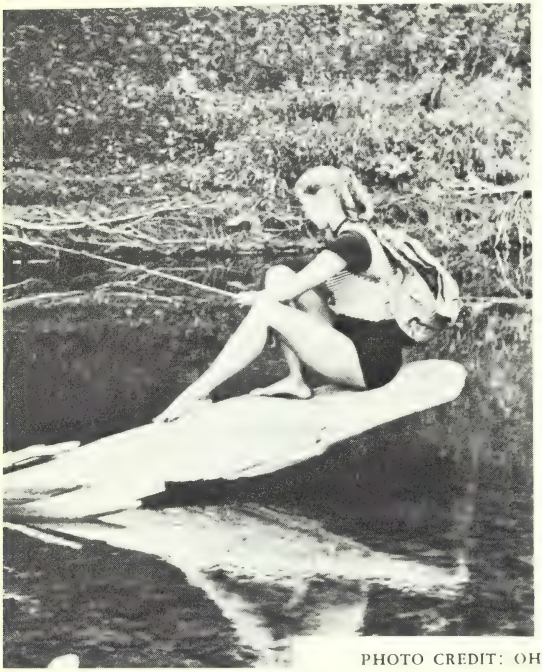


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Figure 4. — Water-oriented activities are very popular on many leased areas.

with 5½ user-days per member, 5 groups reporting. Though largest in number of members, group-family outing organizations ranked last with slightly over 2 user-days per member, 6 groups reporting.

Twelve additional lessees reported activities available to members or users, but did not estimate user-days for 1965. When their information was combined with that of the 29 who estimated user-days, another indication of the popularity of certain activities was possible: percent of all lessees making each activity available (fig. 5).

This tells us more about planned or potential use of leased resources than the user-days summary. It indicates that activities

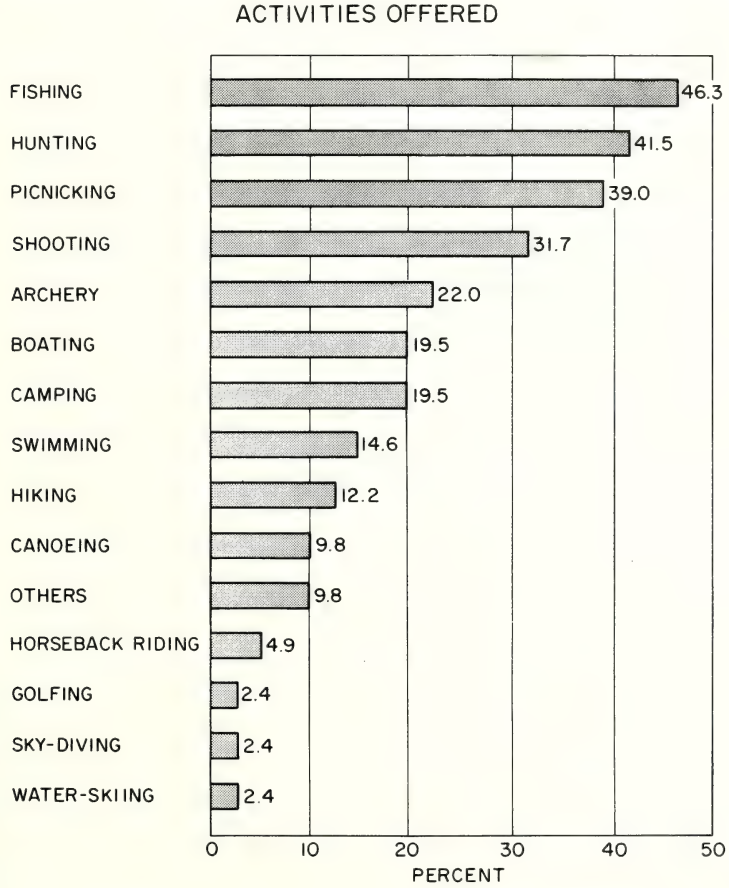

Figure 5. — Percentage of activities offered, based on responses from 41 lessees.

such as archery, camping, canoeing, hunting, and shooting account for a greater share of those made available than they do of the user-days estimated for 1965. Conversely, it is apparent that activities such as boating, fishing, swimming, and water skiing account for a lesser share of activities available than they do of estimated user-days. The importance of this is that even though an available activity may realize few user-days annually, it must often be made available. Perhaps this emphasizes the fact that user minorities are just as important in outdoor recreation as user majorities.

Future Requirements

Ten lessees indicated that they would like to lease more land in the future; only eight indicated how much. The amounts these reported varied from 5 to 3,000 acres, with a median of 25 acres. The minimum acceptable acreage varied from 1 to 1,000, with a median of 10 acres. Length of lease preferred varied from 1 to 99 years, with 5 as a median. Forest-covered land made up 88.9 percent of the acreage wanted by the eight respondents, ponds or lakes 2.4 percent, and open land 8.7 percent.

CONCLUSIONS

Almost any kind of land, lake, or pond can be leased by individuals seeking space for outdoor recreation. Factors of location and the extent to which rental rates are reasonable are among the more important considerations.

Hunting and fishing are two significant uses of leased land in the three States. Together, they accounted for just over 25 percent of the total user-days on leased lands each year. Organizations that were oriented around hunting and fishing as major activities accounted for almost 65 percent of the total acreage leased; annually these organizations paid nearly 30 percent of the aggregate annual lease rental to private landowners in the three States.

Study respondents did not appear to want much more land. However, there no doubt are many other individuals and organizations that could use leased lands if they knew where to find them. The information summarized in this report may help them obtain what they want.

Lumber Grade Yields For Sub-Factory Class

RED OAK LOGS

by James G. Schroeder

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Lumber Grade Yields For Sub-Factory Class RED OAK LOGS

INTRODUCTION

A RECENT study made at Carbondale, Ill., showed that sawing large sub-factory class red oak[1] sawlogs into grade lumber can be profitable. Sub-factory logs are those that will not meet the Forest Service minimum specifications for factory-lumber logs and are generally considered to be, at the best, marginal in quality.

The most recent report of the timber situation in the United States indicates that the ". . . declining quality of timber resources represents a major problem for wood-using industries," but that "projected timber demands to the year 2000 could be met with more intensive forest management and utilization." (*8*)

[1] Red oak, in this report, includes northern red oak (*Quercus rubra* L.), black oak (*Quercus velutina* Lam.), and scarlet oak (*Quercus coccinea* Muenchh.).

What is the quality of our hardwood resource, and how much volume are we talking about? The report (8) summarizes the quality of our eastern hardwood sawtimber resource as follows:

Grade	*Percent*
No. 1 factory-lumber logs (7)	11
No. 2 factory-lumber logs (7)	18
No. 3 factory-lumber logs (7)	48
Tie-and-timber logs	23
	100

The portion of the sawtimber resource in tie-and-timber logs constitutes a volume of 99 billion board feet, but this number does not include the additional billions of board feet in local-use logs. It seems reasonable that the combined volume of sub-factory class sawtimber (tie-and-timber logs and local-use logs) totals at least 150 billion board feet.

If we are to meet the increasing demand for lumber through more intensive forest management and increased utilization, we must find ways to economically process the low-grade segment of our sawtimber resource. We now have little or no information about the conversion value of sub-factory class sawlogs. The study reported here is the first step in determining the value of the sub-factory class of red oak sawlogs. If we assume similar red oak yields for any particular area of operation, the results reported should enable a sawmill operator to determine the marginal log for his particular operation if he knows his costs for converting these logs into factory-grade lumber.

WHAT ARE SUB-FACTORY CLASS SAWLOGS?

Hardwood sawlogs are most frequently segregated on the basis of use classes. Thus, logs meeting the factory class requirements are basically intended to be converted into lumber that later will be remanufactured into smaller defect-free pieces for end uses such as furniture or flooring, for which clear pieces are required.

The sub-factory group of sawlogs can be subdivided further into two classes—the construction class and the local-use class.

Descriptions of these two classes of logs from *A Guide to Hardwood Log Grading* (6) are given in the Appendix. The specifications for construction-class logs are listed in table 1, and examples are illustrated in figure 1. Specifications for local-use logs are listed in table 2, and examples are illustrated in figure 2.

Conversion of logs of these low quality classes into 4/4 lumber is not uncommon, especially in areas where strong markets exist for flooring and pallets. Thus the primary objective of this study was to determine the grade yield of 4/4 standard factory lumber (5) that can be expected from sub-factory class red oak sawlogs,

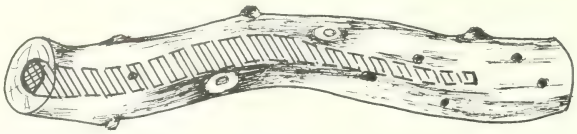
HARDWOOD CONSTRUCTION LOGS

A 10-foot log 18 inches in diameter at the small end. The cuttings on at least two of the four faces are not equal to the minimum required for factory grade 3. Although it has numerous knots, none has a knot collar exceeding ⅓ of the log diameter at the point where it occurs. The log contains no rot, shake, or splits, and it is straight.

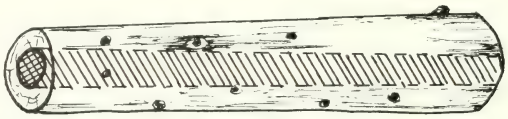
A 12-foot log, 22 inches in diameter at the small end. The cuttings on at least two of the four faces are not equal to the minimum required for a factory grade 3. The numerous knots are small and, although the log is sweepy, the actual sweep does not exceed ¼ of the diameter of the small end of the log. There is no rot, shake, or split.

Figure 1.—Examples of hardwood construction class logs.

LOCAL-USE CLASS

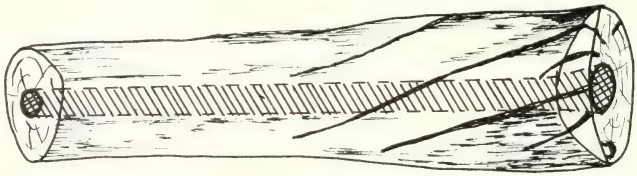


A 14-foot log 16 inches in diameter at the small end. It does not have minimum cuttings required for a factory log. It is too crooked and unsound to meet construction specifications. Sweep and rot deductions are less than 67 percent.



A 12-foot log 18 inches in diameter at the small end. It does not have the cuttings required for a factory log. It has no large knots and no sweep, but it has an unsound heart for which scale deductions will be less than 67 percent.

A 16-foot log 18 inches in diameter at the small end. It does not have the cuttings required for a factory log. Although it is sound, several knots are too large for the construction class.



A 16-foot log 20 inches in diameter at the small end. It does not have the cuttings required for a factory grade 3 log because of the deep spiral seams. It will not qualify as a construction log because of unsound heart.

Figure 2.—Examples of local-use class logs.

Table 1.—*Forest Service standard specifications*[1] *for construction logs*

Position in tree		Butt & upper
Diameter, small end		8 inches +
Length, without trim		8 feet
Clear cuttings		No requirements.
Sweep allowance, absolute		1/4 diameter small end for each 8 feet of length.
Sound surface defects	Single knots	Any number, if no one knot has an average collar diameter in excess of 1/3 of log diameter at point of occurrence.
	Whorled knots	Any number if sum of collar diameters does not exceed 1/3 of log diameter at point of occurrence.
	Holes	Any number provided none has a diameter over 1/3 of log diameter at point of occurrence, and none extends over 3 inches into included timber.[2]
Unsound surface defects		Same requirements as for sound defects if they extend into included timber.[2] No limit if they do not.
End defects	Sound	No requirements.
	Unsound	None permitted except one shake not more than 1/3 the width of contained tie or timber and one split not over 5 inches long.

[1] These specifications are minimum for the class. If, from a group of logs, factory logs are selected first, thus leaving only non-factory logs from which to select construction logs, then the quality range of the construction logs so selected is limited, and the class may be considered a grade. If selection for construction logs is given first priority, then it may be necessary to subdivide the class into grades.

[2] Included timber is always square, and dimension is judged from small end.

Table 2.—*Suggested specifications for hardwood local-use logs*

Position in tree	Butt & upper
Diameter, small end	8 inches +
Length, without trim	8 feet +
Sweep allowance, absolute	1/2 diameter of small end
Total scale deduction allowed	50 to 67 percent
Clear cuttings	No requirements
Surface defects, sound and unsound	Only requirement is that diameter of knots, holes, rot, etc., shall not exceed 1/2 diameter of log at point of occurrence.
Sound end defects	No requirements

and to develop average lumber yield percentages by lumber grade and log diameter. Subsequent studies will be made to determine log values when multiple products such as side lumber, ties, and timbers are produced.

THE STUDY

The study was conducted at the Kaskaskia Experimental Forest in Illinois during two consecutive logging seasons. In both years we took data on red oak logs that were below grade 3 and had a net log scale of 50 percent or more of the gross log-scale volume.

The 235 study logs were placed on rollways and washed to insure that no defects (*4*) were hidden by dirt. Detailed end diagrams and surface diagrams were made of all defect indicators according to standard practices (*1*). Scaling deductions for rot, sweep, and crook were determined and recorded, using the procedure outlined by Grosenbaugh (*2*).

The study logs were sawed at the Kaskaskia Experimental Forest sawmill. Sawing methods were determined by the number of grade faces[2] on the log.

Logs with no factory-grade faces were placed on the carriage so the major defects were located along the edges of the sawing faces. The faces were sawed until the lumber grade dropped below 3A Common, or below the lumber grade obtainable from an adjacent face; the log was then turned 90 degrees, and the next face was sawed as the first. Sawing was continued until the log was completely converted into 4/4 lumber.

Logs with one factory-grade face were placed on the carriage with the grade face against the knees. The opposite face was sawed until the grade dropped below 3A Common, or below the lumber grade obtainable from an adjacent face; the log was then turned 180 degrees, and the grade face was sawed as the first. Next the log was turned 90 degrees, and the third face was sawed as above. Finally, the log was turned 180 degrees, and the fourth face was sawed until the conversion of the log was completed.

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[2] A grade face is a section one-fourth the surface of the log as divided lengthwise that will meet the specifications for a factory-grade sawlog face.

The sawing methods for logs with two factory-grade faces depending on whether the logs had opposite grade faces or adjacent grade faces.

If the log had opposite grade faces, one of the grade faces first was sawed until the grade dropped below 3A Common, or below the lumber grade obtainable from an adjacent face; then the log was turned 180 degrees, and the second grade face was sawed as the first. The log was then turned 90 degrees, and the third face was sawed as above; finally the log was turned 180 degrees, and the fourth face was sawed until the conversion was completed.

Logs with adjacent grade faces were placed on the carriage with one of the grade faces against the knees, and the first poor face was slabbed to provide a bearing surface. The log was then turned 90 degrees, and the second poor face was slabbed as the first. The log was then turned 90 degrees, and the first grade face was sawed until the grade dropped below 3A Common, or below the grade obtainable from an adjacent face when the second grade face was sawed as the first.

The sawing order by faces was indicated on both ends of the logs before they were placed on the carriage. The lumber produced was edged, ripped, and trimmed to obtain the best grade lumber, and efforts were made to minimize volume loss.

After each board was edged, it was numbered with the log number from which it was cut and with consecutive board numbers. If a board was ripped or crosscut, each portion was given the same log and board number. This numbering enabled us to identify individual boards in both green and dry grading and to record both green and air-dry yields for individual logs.

All the lumber produced in the study was graded by a competent lumber grader. The following National Hardwood Lumber Association grades were recognized: First and Seconds, Selects, Number 1 Common, Number 2 Common, Number 3A Common, and Number 3B Common. The length, width, surface measure, and grade were tallied by log- and board-number.

After the lumber was green-graded, it was stacked, and the lumber piles were roofed during the drying period. After the

lumber had reached an approximate moisture content of 20 percent, it was regraded by the same grader.

ANALYSIS OF DATA

The data were combined for analysis. Table 3 shows the actual air-dry lumber grade-yield percentages by log diameter and by lumber grade for all study logs.

Curved lumber grade-yields by log diameter were developed by a least squares fit of the data, using a procedure reported by Jensen (*3*). This curving procedure has been used previously in log- and tree-grade analyses, and it was found to be appropriate. Table 4 shows the curved lumber grade-yield percentages by log diameter and lumber grade for the study logs.

Statistical evaluation of the differences among the three species of red oak was not attempted because of the small number of logs. Differences of practical importance did not occur in the data at hand.

Table 3.—*Actual dry lumber yields by grade for sub-factory class*[1] *red oak*[2] *sawlogs*

Diameter	Logs	Lumber grade-yield						Volume, lumber tally
		FAS	Sel	1C	2C	3A	3B	
Inches	*No.*			*Percent*				*Board feet*
9	6	—	—	—	—	7.1	92.9	170
10	21	—	—	2.7	11.4	17.9	68.0	766
11	36	—	—	3.0	9.4	22.7	64.9	1,637
12	45	—	0.4	3.5	11.7	22.4	62.0	2,159
13	37	—	.2	6.0	18.4	26.7	48.7	2,446
14	28	0.3	1.5	7.6	17.6	28.2	44.8	1,948
15	30	.2	.2	12.0	22.0	30.6	35.0	2,490
16	16	.4	1.2	9.1	22.6	28.7	38.0	1,549
17	9	—	1.7	19.1	32.5	23.8	22.9	818
18	3	—	.9	24.2	30.1	31.1	13.7	322
19	4	1.4	1.6	11.1	22.2	30.8	32.9	441
Average		0.2	0.6	7.9	17.9	26.1	47.3	—

[1] Includes only construction class and local-use class sawlogs.

[2] Includes black oak, northern red oak, and scarlet oak.

Table 4.—*Curved dry lumber yields by grade for sub-factory class*[1] *red oak*[2] *sawlogs*

Diameter	Lumber grade					
	FAS	Sel	1C	2C	3A	3B
Inches			*Percent*			
9	—	—	2	5	8	85
10	—	—	3	8	16	73
11	—	1	3	11	21	64
12	—	1	4	14	24	57
13	—	1	6	16	27	50
14	—	1	8	19	28	44
15	—	1	10	21	30	38
16	—	1	12	24	30	33
17	1	1	14	25	30	29
18	1	1	15	27	30	26
19	1	1	17	28	30	23

[1] Includes only construction class and local-use class sawlogs.
[2] Includes black oak, northern red oak, and scarlet oak.

By combining the data from logs of each species of red oak we were able to compare the value of construction logs with the value of local-use logs. There was no significant difference in value between the two classes of sawlogs.

APPLICATION

If he knows his costs a sawmill operator can use table 4 to determine the marginal sawlog for his particular situation. A hypothetical example will serve to illustrate the procedure.

Problem:

A mill operator has production costs, including the cost of logs, sawing, lumber grading, drying and overhead as shown in table 5. What is the marginal or break-even log that can be sawed under this cost situation when the following prices for air-dry lumber are received?

	Price per thousand board feet
FAS	$200
Sel	$180
1C	$135
2C	$ 85
3A	$ 75
3B	$ 35

Solution:

Multiply the lumber yield percentages (table 4) by their respective selling prices for each log diameter class to determine the average lumber value per thousand board feet:

Example: 17-inch logs:

FAS: .01 x $200 = $ 2.00
Sel: .01 x $180 = $ 1.80
1C: .14 x $135 = $18.90
2C: .25 x $ 85 = $21.25
3A: .30 x $ 75 = $22.50
3B: .29 x $ 35 = $10.15

Lumber value per thousand board feet for 17-inch logs = $76.60.

Table 5.—*Log lumber values and log-processing costs*

Diameter (inches)	Average lumber value per thousand board feet	Average variable costs per thousand board feet[1]
9	$42.70	$72.50
10	48.40	71.25
11	53.35	70.00
12	57.05	69.00
13	61.25	68.25
14	65.15	67.60
15	68.95	67.00
16	72.45	66.25
17	76.60	65.70
18	78.60	65.00
19	81.10	64.50

[1] Costs in this example from: Keppler, William E. and Thomas P. Fetters. LOGS—THE CRITICAL MILL INPUT. N. Logger 16(3): 22-24. 1967.

The average lumber values per thousand board feet for the logs is shown in table 5.

The marginal log for the sawmill in this example falls between 14 and 15 inches in diameter (the point at which the value of the lumber from the log is equal to the cost of producing the lumber). Logs 15 inches in diameter or larger will, on the average, yield a profit to this mill owner. On the other hand, this owner should reject logs less than 15 inches in diameter because the value of the lumber produced from these logs does not equal the cost of producing it.

A person wishing to apply these data to his own particular operation must substitute his own costs for those used in the example, and must also use his own lumber selling prices to determine his log value.

DISCUSSION

It is not known if these data will apply to sub-factory class sawlogs of other species, but it is very likely that the yields from other oaks would not differ materially from the yields presented in this paper because of the relatively low values involved. A sample of approximately 50 logs should be sufficient to compare other oak yields to the red oak yields if an operator wishes to make this test.

It is possible that conversion of all or some of these logs into products other than 4/4 lumber would yield higher returns. For example, if a sawyer cuts the No. 2 Common and Better Portion of the log into 4/4 factory lumber and converts the remainder of the log into structural items, the returns might be higher than they would be if only factory lumber were produced. A mill operator will be able to make this decision based on prices he receives for products other than factory lumber.

■

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APPENDIX

Construction Class Sawlogs

This class includes logs suitable for sawing into ties and timbers and other items to be used, more or less intact, for structural or weight-bearing purposes. Grade specifications are contained in the construction-lumber section of the National Hardwood Lumber Association rules; the tie specifications of the American Railway Association; and the standard specifications for structural wool joists and planks, beams and stringers, and posts and timbers of the American Society for Testing Materials.

In general, these specifications are designed to insure the strength of a piece. In the usual run of logs suitable for this use, the position and condition of the heart are especially important factors. Knots and other defects that would impair the strength of the product are limited to sizes that hold impairment within acceptable limits.

Although factory-lumber grades allow for progressively more defects from the high grades to the low grades, construction specifications are rigid throughout with regard to the inclusion of weakening imperfections. This results in long requirements different from those for factory-lumber use. For example, a factory log with a rotten, shaky interior, and with large but widely spaced individual defects, may produce enough high-grade boards so that a high average quality of yield can be obtained. Yet such a log would be practically worthless as a construction log.

Local-Use Class

In general, local-use logs are those that are suitable for products not usually covered by any standard specifications. High strength, great durability, or fine appearance are not required in these products. These logs are generally sold in local or restricted markets for use in secondary farm buildings, crating, mine ties, and industrial blocking. Whereas the products of the other two classes are usually sold over a wide area and through a variety of marketing channels, local-use materials are generally sold directly to the user by the producer. This often makes the handling of local-use logs rather profitable.

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Sap Yields from **FALL AND SPRING TAPPING** *of Sugar Maple*

by Melvin R. Koelling

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Sap Yields from FALL AND SPRING TAPPING of Sugar Maple

WILL FALL TAPPING INCREASE SAP YIELD?

SOME maple sap producers have wondered whether they could increase the total sap yields by tapping their trees not only in the spring but also in the fall too. Our research indicates that tapping in the fall cannot be recommended.

Our study of fall tapping was begun in November 1964. Fall tapping was at least theoretically possible because temperature fluctuations like those of the normal spring tapping season occur to some extent in late fall and early winter. However, it was not known whether the volume and sugar concentration of fall-produced sap would be adequate to make such a practice feasible. Nor did we know whether fall tapping would affect the normal spring sap production from fall-tapped trees. The study reported here was set up to answer these questions.

STUDY METHODS

Ten large sugar maple trees located in each of two northern Vermont sugarbushes were tapped in late October 1964 and again in 1965; tapholes were located on the north, east, south, and west side of each tree (fig. 1). These tapholes, and all others used in this study, were 2½ inches deep (total depth) and 7/16 inch in diameter. All were located approximately 45 inches above the ground. After tapping, a paraformaldehyde pellet was placed

Figure 1.—Typical large, open-grown sugar maple trees like these were used for fall tapping experiments.

in the back of each hole and sap collection equipment (metal spout and plastic sap bag) was installed. The total volume and average sugar concentration of all sap produced during the fall were recorded for each taphole on each tree.

In February, each year, all spouts and collection equipment were removed from the trees. The existing tapholes were then reamed with a ½-inch drill bit; new paraformaldehyde pellets were inserted in each hole; and the collection equipment was re-installed. At the same time, 10 adjacent trees on each sugarbush that had not been tapped in the fall were tapped with four tapholes located and equipped as mentioned above. Sap volume and sugar concentration were recorded until the last week of April for each tree.

The effects of fall tapping on normal spring yields were studied further in the fall and spring of 1965-66 when we used a different method of re-tapping in the spring. In this phase of the work, 48 trees were paired on the basis of similar yield during the 1964-65 sugaring season. During the first week in November 1965, one member of each pair was randomly selected for tapping. Tapping consisted of drilling two tapholes—one on the north side and one on the south side of each tree. Sap collections and sugar determinations were recorded from each tap through February 15, 1966. At that time all spouts and collection equipment were removed from each taphole, and the tapholes were plugged with a cork. A new taphole was then drilled approximately 5 inches to one side of each of the plugged tapholes. Concurrently, the other member of each pair of trees was tapped with two tapholes (north and south) each. Volume collections and sap sugar concentrations were recorded for all trees until April 28, 1966.

RESULTS AND DISCUSSION

Volume of Fall-Produced Sap

The study clearly showed that sap can be obtained from tapped maple trees during the fall. However, both the amount and the sugar concentration of this sap were lower than that obtained during the normal spring tapping season.

An average of 2.45 gallons of sap was obtained from each taphole in the fall of 1964 (table 1). The yield from these same trees in the spring (after reaming of the taphole) amounted to 5.54 gallons. The other set of similar trees in the same sugarbush that were tapped only in the spring yielded 8.07 gallons of sap.

When these same trees were tapped in a similar manner during the fall and spring of 1965-66, slightly larger volumes of sap were obtained (table 1), but the relationships between fall and spring yields were nearly identical with the 1964-65 results. For all trees in both years, fall sap yields were approximately one-third the spring yields from trees not fall-tapped.

The reduced fall yields may be related to the frequency and range of air temperature fluctuations throughout the tapping period. Favorable sap production days—i.e., cool nights (below 32° F.) followed by above-freezing days—do not occur as often in the fall as in the spring. Likewise, the length of the below-freezing period is usually greater in the spring than in the fall.

Table 1.—*Average volume and sugar concentration of sap produced per taphole from trees tapped both in the fall and in the spring, and in the spring only*

Tapping period	Volume in gallons	Sugar concentration in percent
TAPHOLES REAMED IN SPRING		
Fall and spring:		
Nov. 1, 1964—Feb. 11, 1965	2.45	1.9
Feb. 12, 1965—May 5, 1965	5.54	3.1
Spring only:		
Feb. 12, 1965—May 5, 1965	8.07	3.0
Fall and spring:		
Nov. 1, 1965—Feb. 15, 1966	4.18	1.8
Feb. 15, 1966—April 28, 1966	6.27	2.5
Spring only:		
Feb. 16, 1966—April 28, 1966	11.96	2.7
NEW TAPHOLES IN THE SPRING[1]		
Fall and spring:		
Nov. 1, 1965—Feb. 15, 1966	6.26	2.4
Feb. 15, 1966—April 28, 1966	17.04	3.3
Spring only:		
Feb. 15, 1966—April 28, 1966	25.15	3.0

[1] Yields from trees paired on the basis of previous yields.

The range in air temperature during the fall also may affect the recharge process within the tree. Marvin (*1958*) has noted that the flow of sap is more or less proportional to the conditioning period that precedes sap flow. In general, the longer the sub-freezing period before a period of above-freezing temperatures, the greater the flow and amount of sap produced. The reduced length and severity of this sub-freezing period in the fall may reduce water recharge within the tree, and thereby reduce the potential for large yields.

Soil moisture levels also may affect fall sap yields. The normal spring season often is characterized by melting snow and frequent rainy periods that result in excessive soil moisture. This readily available source of moisture in the surface soil horizons may contribute to more rapid recharge in the tree and larger volume production. In the fall, these higher moisture levels are usually not present.

Sugar Concentration of Fall-Produced Sap

A second distinguishing feature of fall-produced sap is its low sugar concentration. The average values of 1.9 and 1.8 percent contrast sharply with the values of 3.0 and 2.7 for trees similarly tapped in the spring (table 1). This difference is important in sugaring operations. Approximately 44 gallons of 1.9-percent sap are required to produce 1 gallon of standard density syrup, but only 29 gallons of 3.0-percent sap are required. Production costs would be increased considerably in processing the lower sugar-content sap.

These low sugar concentrations in fall-produced sap are thought to be related to carbohydrate transformations within the tree. Starch accumulates in most woody plants throughout the summer and reaches a maximum in early autumn (*Kramer and Kozlowski 1960*). With the beginning of winter this starch content begins to decrease with a concurrent increase in sugar, most often in the form of sucrose. In general, this starch transformation process is associated with and accelerated by decreases in temperature. Kramer and Kozlowski indicate this is rather unusual because "one would expect chemical reactions to be slowed down by tempera-

tures near freezing." They conclude that perhaps some inhibitor of enzyme action is present at high temperatures which disappears during a period of low temperature. Thus, sugar in the tree should build up in the spring after the cold winter temperatures; and this spring buildup could account for the higher spring sap-sugar concentrations.

Effect of Fall Tapping of Spring Sap Yields

Spring yields for trees tapped in the fall and those not tapped in the fall differed considerably. The two spring volume yields, 5.54 and 8.07 gallons (table 1), were significantly different at the 5-percent level. But the sugar concentration in the sap during spring flows was approximately the same for those trees tapped both in the fall and spring and those tapped only in the spring.

We do not know what factors are responsible for these spring volume differences. One possibility is that the potentials for sap production were not equal for both groups of trees because the fall-tapped trees had reamed tapholes in the spring but the spring-tapped trees had newly constructed tapholes. Some dead or desiccated tissue may have remained in the fall tapholes even after reaming, and this might have reduced sap flow from these tapholes. A recent Canadian investigation (*Maritimes Arboretum 1965*) indicated that reaming was not a satisfactory substitute for new tapholes if maximum sap yields were to be obtained.

However, the method of re-tapping was eliminated as a possible cause of spring yield differences when we used a different method of re-tapping in 1965-66. Instead of reaming existing holes, we drilled new holes in these trees. With this method of re-tapping, trees that had been tapped in the fall still produced significantly less (1-percent level) sap than trees not tapped in the fall (table 1). Non-significant differences were found in average sap-sugar concentrations for these trees.

These results suggest that fall tapping has a detrimental effect on spring yields. Comparisons of the fall plus spring yields of trees tapped in the fall with the yields of trees tapped only in the spring also reveal that *total* yields are essentially equal (table 1).

For example, in 1964-65 the combined fall and spring yield of 7.99 gallons is very close to the 8.07 gallons yield of trees tapped only in the spring. Similar figures for 1965-66 are 10.45 and 11.96 for the group with reamed tapholes and 23.30 and 25.15 for the group with new tapholes.

Most of the reduction in spring yield from fall-tapped trees occurs in late spring:

	Sap yield	
	Early spring '66 (gallons)	*Late spring '66 (gallons)*
Fall-tapped trees	10.34	6.70
Trees not fall-tapped	11.78	13.37

Thus, apparently fall-tapped trees simply run out of material sooner than trees that have not been fall-tapped. And the fact that the amount of the late spring reduction is essentially equal to the yield obtained in the fall suggests that each tree has a fixed potential that is not much affected by the timing of the sap removal.

Possibly the amount of carbohydrate (sugar) available for sap is fixed within a tree; reduction of this substrate below a certain level may trigger physical or chemical changes within the tree that stop sap flow even though moisture is available and weather conditions are favorable. Additional research on the mechanisms of sap production, storage, and flow will be required to explain adequately the reduction in spring sap yield of trees also tapped the previous fall.

However, regardless of the physiological reasons for these results, we do not feel we can recommend fall tapping. It provides no increase in total sap production and reduces the amount of sugar obtained from each tree.

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A Summary and Evaluation of Research on the Use of PLASTIC TUBING in Maple Sap Production

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A Summary and Evaluation of Research on the Use of PLASTIC TUBING in Maple Sap Production

THOUGH use of plastic tubing for collecting maple sap has been hailed as the greatest advance ever made by the maple sugar industry, relatively few maple sugar producers are using tubing systems. To point the way toward greater and more efficient use of tubing systems, we summarize here the results and observations of our experiments with this method of sap collection.

The introduction and use of flexible plastic tubing in the maple sugar industry probably is the most significant change that has occurred since the beginning of this 300-year-old industry. The use of properly installed and maintained plastic tubing systems has made possible the expansion of sugaring operations into areas that formerly were unworkable because of rough topography. One- or two-man operations involving 1,000 or more taps now are possible because the use of tubing eliminates the need of a large labor force for collecting sap. Willits and Sipple *(1961)* estimate that use of tubing can eliminate as much as 40 percent of the cost of syrup-making.

Nevertheless tubing has not enjoyed widespread use, in spite of the fact that it was originally recommended as a panacea for all the ills of the maple industry. Only 9 percent of all maple producers are now using tubing.[1]

There are several reasons why this collection system has not been adopted widely by the industry. For one, the initial cost of a tubing installation is relatively high. Willits and Sipple *(1961)* estimated that the cost of a tubing installation is about $1.25 per taphole. Morrow *(1961)* reported that the cost of tubing exceeded the cost of buckets by 16 to 20 cents per taphole per year. Besides, most producers are already equipped for a bucket operation. The resale value and demand for buckets is very low; thus tubing represents both a new investment and a loss on equipment already on hand. Whether such reasoning is economically sound in view of the labor savings associated with tubing we do not know.

A second reason why tubing has not been more widely accepted is that some operators could not make the system work. Misconceptions about the operation of tubing systems were common *(Willits 1965)*. These affected the design of some systems in such a way that maximum yields were not obtained. Also, recommendations for laying out and setting up tubing systems were often based on observation rather than designed experiments. As a result, the maple producer who tried this new approach to

[1] Based on a talk by W. F. Cowen, Jr., at the Geauga County Institute of Forestry and Maple Syrup Production and Marketing, in Burton, Ohio, 27 January 1966.

sap collection was often dissatisfied with results, and it was not unusual for him to abandon tubing and return to using buckets. Although improvements and refinements in both tubing and its use have been made, many producers are still reluctant to try it.

Certainly, if the efficiency of plastic tubing can be improved, it will be more widely used, and the industry as a whole will benefit. In this report we have summarized the results and observations of tubing experiments conducted by the Northeastern Forest Experiment Station that suggest some ways in which this increased efficiency can be obtained.

STUDIES & FINDINGS

The Question of Venting

One of the questions about use of tubing is whether or not the spouts should be vented. Some people think that a tubing system vented to allow air in will permit better flow of sap than one without vents. On the other hand, a few producers have found that, under the right circumstances, unvented tubing will yield more sap than vented tubing.

Venting is one of the major differences between the two commercially recommended methods of installation. Some research data on differences in sap yield between vented and unvented systems are available *(Laing, Marvin, and Chamberlain 1964)* but strong differences of opinion continue to exist *(Sipple 1967; Willits 1965)*. A recent study conducted by personnel of the Northeastern Forest Experiment Station *(Blum 1967)* provides detailed yield comparisons between vented and unvented aerial tubing systems.

In this study two tapholes were used on each tree. One taphole was fitted with a vented spout and the other was fitted with an unvented spout. Each of these paired tapholes was connected to a separate but identical tubing system. In all, we used fifteen pairs of tubing systems, one vented and the other unvented, each collecting sap from about 20 trees. All lines in both systems were suspended by stretching the tubing from tree to tree. Sap yield

from the unvented tubing was about 40 percent higher than that from the vented systems during 1966.

In 1967, three similar studies were conducted in Vermont, New Hampshire, and Massachusetts. Yields from the unvented systems in all three states averaged 34 percent more than those from the vented systems.

In evaluating factors responsible for yield differences between the two methods, two possibilities were considered. (1) Either sap was lost through vents on the vented systems, or (2) sap yield was greater from the unvented system because of some attribute of that system.

Our studies indicated that very little sap was lost through the vents. Actual measured vent losses represented less than 3 percent of the total seasonal yield of the vented members. Though the size of this loss could be expected to exhibit some yearly variation due to temperature conditions and care in the installation of the lines, it is unlikely that it would ever account for the observed yield differences of 40 and 34 percent.

The Effect of Vacuum

Observation of the unvented tubing lines during periods when sap was flowing indicated that considerable vacuum was being developed as a result of sap movement in the closed system. This vacuum was evidenced by distortion of the tubing (but never to the point of collapse or closing) on some lines (fig. 1). The possibility of a relationship between vacuum levels and yield differences between vented and unvented lines was therefore suggested.

Vacuum levels were measured at the upper end of each line, and these values were plotted against the seasonal yield difference between lines for each pair. A strong linear relationship was found to exist (a correlation coefficient of 0.86 for 1966 data). Thus the difference appears to be an increased yield from the unvented system, which is related to the presence of vacuum in that system.

Two additional questions about venting and vacuum relationships remained to be investigated. (1) Will vacuum develop in

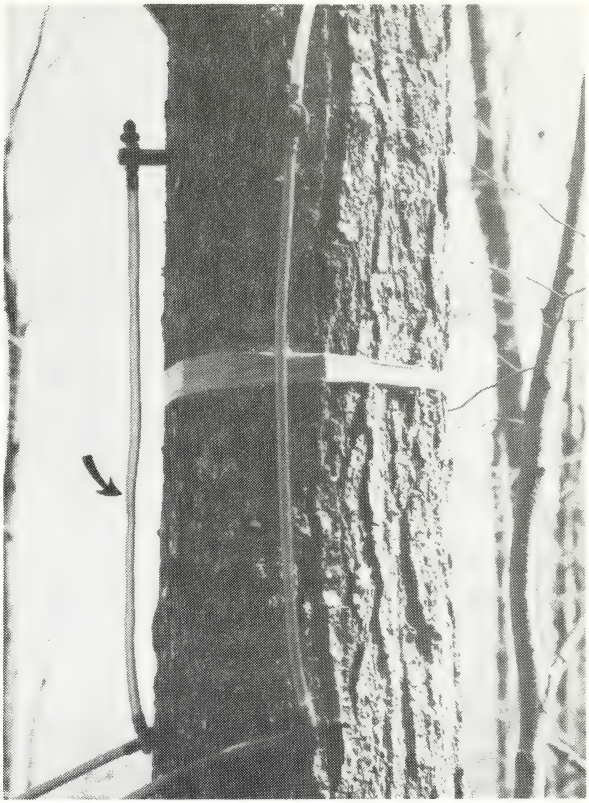

Figure 1.—Self-developed vacuum was strong enough to distort the tubing in the unvented line on the left.

unvented ground-line tubing installations the same as in these aerial installations? And (2) what would be the effect of sustained artificial vacuum on sap yield? Studies designed to answer these questions were made during the 1967 sugaring season.

Ground Line Installations

To study venting in ground-line installations, we used the same methods as those we used in our studies of suspended installations except that 4-foot drop lines were added, and the most recent recommendations for ground-line installation were followed *(Sipple 1967)*. Vacuum measurements on the unvented lines were recorded twice during the season when sap was flowing. Losses of sap through the vents were also measured.

The total sap yield from this experiment for the 1967 season averaged 7.9 percent greater for the unvented lines. This difference was not significant, although a significant correlation coefficient of 0.73 was obtained between vacuum levels and sap yield differences between lines. Vent losses amounted to less than 1 percent of the total vented yield.

The relatively small and nonsignificant increase in yield from the unvented lines in this study appeared to result from a reduction in the amount of vacuum developed in the ground-line installation. Any obstacle to natural movement of the sap by gravity, such as slight hummocks or elevation in tubing caused by too short a drop line (fig. 2), will reduce the amount of vacuum developed. If all such restrictions to flow had been eliminated, yield increases from the unvented line might have been substantially larger. This assumption is supported by the significant correlation between yield differences and the measured vacuum levels.

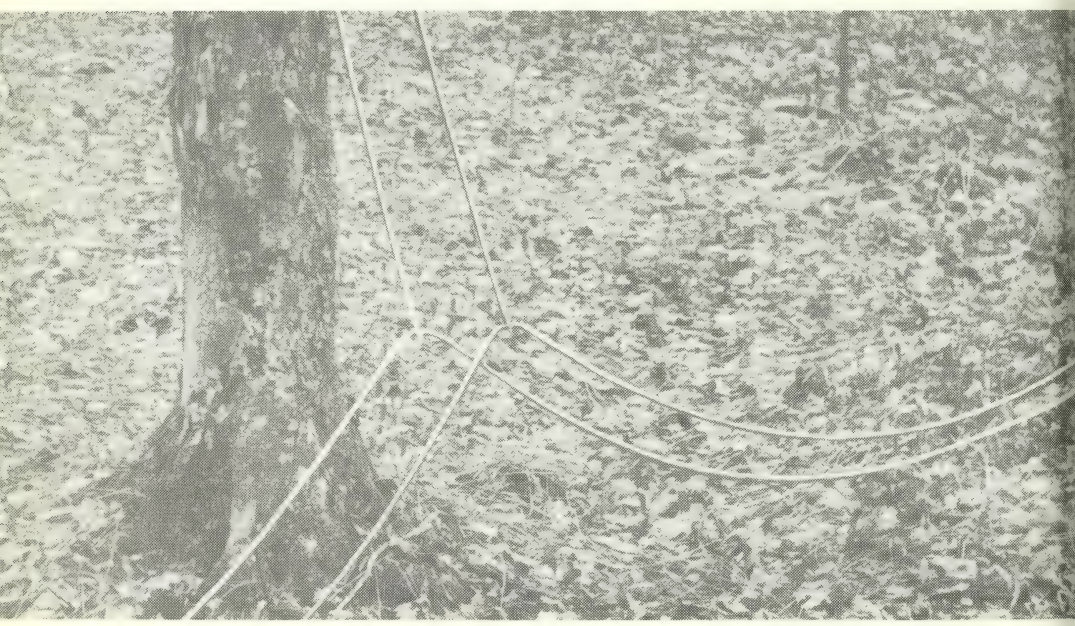

Figure 2.—Elevation in tubing caused by too short a drop line could result in decreased sap yields on unvented ground-line installations on gentle slopes.

Pumping Studies

The effects of artificially applied vacuum on sap yield were investigated next. Approximately 171 trees were tapped with two tapholes each, spaced 6 inches apart at breast height. One taphole was fitted with an unvented spout and the other with a vented spout. Each of the spouts was fitted with an 18-inch drop line, which led to separate tubing systems, one vented and the other unvented. Branch lines were aerially installed and main lines were laid on the ground. These systems were parallel to one another, and both were installed so they could operate efficiently by gravity alone.

An electric jet-type vacuum pump operating on the venturi-tube principle was installed at the collection tank for the unvented system. A vacuum line from the pump was attached to the unvented main line in such a way that vacuum could be directed to all the unvented tapholes; or when vacuum was not applied, sap could bypass the pump and flow by gravity into the collection tank. Measurements of sap flow were kept both when the pump was operating and when flow was occurring naturally.

Our results showed that for a gravity system, use of unvented tubing increased sap yield 43 percent (184 gallons or 1.1 gallons per tap) over that obtained with vented tubing; and that vacuum pumping increased yield 385 percent (567 gallons or 3.3 gallons per tap) over that obtained by natural flows.

DISCUSSION

In view of these study results, we can make several observations about the installation and use of tubing for maple sap collection. We can also make inferences pertinent to the use of tubing in other locations under other environmental conditions.

Venting versus Not Venting

The question of whether to vent or not to vent all spouts in a tubing installation is one that the individual maple producer must answer for himself. The primary factor related to increased sap yields from an unvented system is self-developed vacuum.

In all studies, a significant relationship was obtained between yield increases from an unvented system and the amount of vacuum at the head of each line. This vacuum is principally a result of the slope, length of the tubing line, and amount of sap in the line. When slope is sufficient (8 to 10 percent or more) and a fairly continuous grade can be maintained, greater sap yields can be expected from an unvented system than from a vented system.

At least 20 taps are desirable for each line in order to have the system work efficiently. There is some indication that an increase in the number of tapholes up to 35 per 5/16-inch branch line will result in greater yields. Whether this effect will be obtained by more than 35 tapholes remains to be determined.

Aerial versus Ground Lines

The yield increases obtained from using unvented tubing were found to be greater with aerial systems than with ground-line systems (about 38 percent versus about 8 percent). As stated previously, much of this difference seems to be due to restrictions in natural downhill flow of sap, which reduces vacuum in the ground-line system.

In aerial systems, minor variations in topography are eliminated by varying the taphole height and stretching the tubing to maintain a more uniform grade. If all such restrictions to flow were eliminated, unvented ground lines could be expected to compare favorably with unvented aerial lines. Although care is important in laying out and setting up either tubing system, it seems easier to obtain a satisfactory installation and the accompanying increases in sap yield with suspended tubing.

There are some additional advantages to an aerial system. In the initial installation, considerably less tubing will be used than in a ground-line system. The actual amount of tubing saved is about 3 to 4 feet per taphole. At the current price of $0.04 per foot for 5/16-inch tubing, this will result in a financial savings of $120 to $160 on a 1,000-tap operation. The reduction in the amount of tubing required is the result of shorter drop lines and less tubing required to go from tree to tree.

A second advantage of an aerial installation over a ground line is the reduction in time required to pull the tubing out of the snow. This advantage will vary by region, and is more important in areas of heavy snowfall. With ground lines, considerable labor is required to complete this task, while in an aerial system the problem does not usually occur.

However, an aerial system is not without some disadvantages. Its effectiveness may be reduced in sugarbushes where the trees are widely spaced and where much sag occurs in the lines between trees. This problem may be greatly alleviated by placing a few temporary supports between widely spaced trees and by careful planning of the initial installation. If considerable slope is present between widely spaced trees, sag is not a problem.

Care in taphole location and initial layout of the tubing is also more critical for an aerial system than for a ground-line system. Taphole height is especially important in sugarbushes with gentle slopes. However, this disadvantage can also be an advantage in sugarbushes with little or no slope, as some artificial grade may be built into the aerial system by varying taphole height.

Vacuum Pumping

Increases in sap yield from a pumped vacuum system were noted during days of both good and poor sap flow. However, the greatest advantage in pumping was obtained during periods when natural flow was very slow, and it was possible to obtain a considerable volume of sap by pumping on days when natural sap flow was almost nil. The sap obtained under such conditions represents a yield that would not have been obtained at all by bags, buckets, or tubing operating by gravity.

Aside from increasing the yield of sap, vacuum pumping reduces some of the problems associated with tubing. Since vacuum empties the tubing lines, freezing of sap may not be a major problem. And the maintenance of a uniform slope or grade in all tubing lines is not as critical as for a gravity-flow system. However, a pumped system that will let sap flow by gravity is desirable, because some flow may occur when vacuum is not being applied.

A question of primary importance to maple producers who

might use vacuum pumping is: How many tapholes may be connected to a central vacuum pump? Certainly, the number is greater than the 171 used in our study; however, an absolute maximum number has not been established. It will probably depend on the integrity of the tubing system, the efficiency and capacity of the vacuum pump, and the amount of vacuum desired at each taphole. Since even a small amount of vacuum is of value in increasing sap flow, the actual number of tapholes per pump may be large.

The advantages of vacuum for increasing sap yield have been demonstrated. However, the decision of the maple producer on whether or not to use vacuum pumping will probably hinge on two other questions: (1) How much will a vacuum installation cost?; and (2) How will sustained vacuum pumping affect the health of individual trees in his sugarbush? To be of value, vacuum pumping must not only be economically feasible; it must also not adversely affect the health of trees in the sugarbush.

The vacuum pump used in our study cost $175[2] and the power source, a 3,300-watt generator, cost $300. The installation of valves so sap could bypass the pump added another $15. Operation of the generator during the season cost approximately $14. Total cost was about $504. This represents the added cost above that for an unvented aerial tubing system. Total cost would have been approximately $300 less if commercial power had been available.

If the increase of 3.3 gallons of sap per taphole obtained in this study as a result of pumping were applied to a 1,000-tap operation, an increase of 3,300 gallons of sap could be expected. At $0.05 per gallon for sap, this would represent a value of $165. If this value were applied to the fixed costs of pumping, then the complete system would pay for itself when the second season of use is approximately one quarter over if commercial power is available, and at the end of the third season if a generator must be purchased. While these values serve only as a relative indication of the costs

[2] This price is f.o.b. Leader Evaporatory Co., St. Albans, Vermont. Mention of a trade name should not be construed as endorsement by the Forest Service or the U.S. Department of Agriculture.

of vacuum pumping, it is apparent that cost should not be a major problem.

We have little information about how vacuum pumping affects tree health. However, the effect is believed to be minor because the amount of sap removed by either natural flow or pumping represents an extremely small portion of the total moisture capacity of a tree. The 40 gallons or so of sap removed throughout the season from an average-size tree is only a fraction of the amount of water that may be transpired through the leaves on a summer day. Furthermore, observation of approximately 1,000 trees that have been vacuum-pumped for the past 10 years have revealed no peculiar disease problems, insect infestations, or other harmful side effects.[3]

SUMMARY AND CONCLUSIONS

The use of plastic tubing can significantly reduce the labor and cost involved in collecting maple sap. However, only about 9 percent of the present producers were using tubing in 1966; this is due to a combination of factors, including high initial cost, disagreements on design and installation methods, and poor initial success on the part of some users.

Results of designed studies reported here provide infomation about the effectiveness of various tubing design and installation methods, and suggest certain ways in which tubing can be used to increase sap yields. These results emphasize the potential advantages of tubing as a collection system, and should encourage its increased use. Specific conclusions from our studies include the following:

- Increased sap yields may be obtained from an unvented tubing system under certain conditions. This increased yield is related to self-developed vacuum in the unvented lines. To obtain this vacuum and the associated yield increases, the tubing must be installed with sufficient slope in the lines, and restrictions to natural gravity flow must be avoided.

[3] These trees are located on the farm of Gerard Caron, Westford, Vermont. His average yield has been about 1/3 of a gallon of syrup per taphole.

- In general, an aerial unvented tubing system requires less tubing and will function better than a similar ground-line system, especially on gentle slopes. However, a combination of factors should be considered in deciding which system is preferable for an individual producer.
- The application of artificial vacuum to an unvented tubing system results in large yield increases — nearly a four-fold increase in our studies. Though this effect was found during both heavy and weeping flows, its effect was especially pronounced on days when natural flow was very slow.

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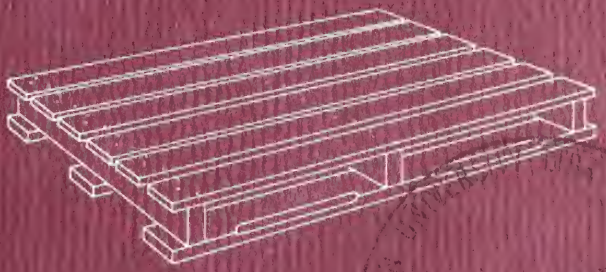
THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

The Department of Defense Market for WOODEN PALLETS: 1965



by John T. Lucas
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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
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THE MARKET

ONE OF THE big markets for wooden pallets is the Department of Defense. For the benefit of pallet suppliers, a study of this market has been made to show them what kinds of pallets DOD uses, how DOD purchases pallets, when and where pallets are needed, and what problems are associated with selling to DOD. And for the benefit of DOD materials-handling personnel, information is included about locations of pallet suppliers, problems suppliers are confronted with when selling to DOD, and initial price ranges for pallets.

The Department of Defense (DOD) market for wooden pallets has two segments — direct and indirect. The Defense General Supply Center (DGSC) in Richmond, Va., constitutes the direct market. Other DOD installations, the General Services Administration (GSA), and private industrial firms that supply goods on pallets to DOD constitute the indirect market. About one-half of the wooden pallets used by DOD are purchased by DGSC.

This study is concerned primarily with the direct market. And all information relates to market conditions of 1965 and 1966 unless reference is made to a different year or time period.

BACKGROUND

The Armed Forces' need for materials-handling platforms during World War II was almost entirely responsible for the development of the wooden pallet industry. Before then few pallets were being used by DOD or by private industry. From 1940 through

1945, DOD required 55 to 60 million wooden pallets.[1] Because there were few commercial wooden pallet manufacturers at that time, most DOD pallets were fabricated by sawmill operators and DOD personnel.

After World War II, most DOD wooden pallet requirements were satisfied through purchase: in 1948, 1.2 million were purchased; in 1950, 1.7 million.[1] Although DOD wooden pallet purchases increased from 1948 to 1950, the market became less important to the wooden pallet industry: 1948 purchases consumed 19 percent of commercial wooden pallet production; 1950 purchases, 7 percent. Since 1950, annual DOD wooden pallet purchases have varied appreciably, depending primarily on periodic availability of funds and degree of armament.

Before 1962, wooden pallets were purchased by the installation that needed them. As part of Defense Secretary McNamara's centralized procurement program, DGSC was given responsibility for procuring certain goods for the entire DOD. Standard wooden pallets (table 1)[2] were among these goods. Now DGSC procures practically all wooden pallets requisitioned by DOD installations; nonstandard wooden pallets and wooden pallets for emergency and experimental needs may be purchased by individual DOD installations upon approval from the commanding service or agency if the order is less than $2,500.

QUALITY AND QUANTITY REQUIREMENTS

About 95 percent of all wooden pallets purchased by DOD are described by fully coordinated specifications (and purchase descriptions). Fully coordinated specifications are approved for use by all components of DOD. The remaining 5 percent are described by limited coordinated specifications (and purchase descriptions). Limited coordinated specifications are usually for pallets that will only be used at one installation or by only one branch

[1] U.S. Forest Service. REQUIREMENTS, PRODUCTION, AND SUPPLY OF WOODEN PALLETS. 18 pp., illus. 1950. (Unpublished report on file at the U.S. Forest Service Division of Forest Economics and Marketing Research, Washington, D. C.)

[2] All tables are in the appendix.

of the Armed Forces. Most fully coordinated specifications are prepared by the U. S. Navy Supply Systems Command, Washington, D. C., or the U. S. Army Mobility Equipment Command Research Laboratory, Development and Engineering Directorate, Fort Belvoir, Virginia.[3] Limited coordinated specifications are prepared at other DOD installations. Specifications are based on laboratory and service tests of the pallets, performance requirements dictated by the facilities and equipment available for storage and transportation, and handling characteristics of products to be shipped.

The specifications are identified by code designations — MIL-P-15011E, MIL-P-3938B, NN-P-71b, and others (table 1). They are revised when it is necessary to clarify misunderstandings and misinterpretations, to standardize terminology and format, and to make modifications needed to conform with changes in supply requirements. When a specification is modified, the letter to the right of the number (E, B, and b in the above example) is changed, or a written amendment is issued.

All standard DOD items are identified by Federal Stock Numbers (FSN's). The first four digits of an FSN designate the Federal Supply Class of items, and all pallets are designated by Class 3990. The remaining seven digits comprise the Federal Item Identification Number (FIIN), and each pallet is designated by an FIIN. Practically all wooden pallets purchased by DOD are described by the 20 standard FIIN's listed in table 1.

DOD is trying to restrict the introduction of new pallet FIIN's and to reduce the number now in use. DOD has designated a partial four-way entry stringer pallet (FIIN 599-5326) as the primary pallet for procurement and general-purpose use within DOD (*14*). Standardization recommendations made in a recent U. S. Navy Supply Systems Command technical report (*17*) are: (1) procurement of wooden pallets should be limited to FIIN 599-5326; (2) a four-way entry post pallet (FIIN 141-7261) should be authorized for purchase in place of FIIN 599-5326

[3] The U.S. Navy Supply Systems Command was formerly called the U.S. Navy Bureau of Supplies and Accounts. The technical pallet research conducted at Fort Belvoir was formerly conducted by the U.S. Army Natick Laboratories, Natick, Massachusetts.

when the four-way entry attribute is necessary; and (3) some of the other standard kinds of pallets should be phased out or similar specifications should be combined.

Efforts are now under way to have the post pallet (FIIN 141-7261) replace the notched-stringer pallet (FIIN 599-5326) as the primary kind of pallet to be approved for purchase throughout DOD. The post pallet is being recommended because (1) goods can be strapped to it quicker by automatic machinery than they can be strapped to the notched-stringer pallet; (2) some DOD materials-handling experts believe that goods are more likely to fall off a notched-stringer pallet when it is being moved by a forklift that has entered through the notches (perpendicular to the stringers); and (3) it is being used by most of the NATO nations. Other possible advantages of using post pallets rather than stringer pallets are: unloaded post pallets can be nested to take up less storage space; and post pallets allow for better ventilation of unit loads in storage.

Before 1966, most pallets purchased by DGSC were constructed of seasoned hardwood lumber with a maximum moisture content of 22 percent in deckboards and 26 percent in stringers and posts. However, because hardwood lumber — particularly seasoned hardwood lumber—was scarce in 1966, DOD temporarily waived the moisture content limit and began to purchase softwood pallets in place of hardwood. During the last part of 1966, three new FIIN's were added to the standard list to conform with lumber supply changes. These FIIN's were 926-1046, 926-1047, and 926-3748. FIIN's 926-1046 and 926-1047 describe the same pallets as do FIIN's 141-7261 and 599-5326 respectively, except that moisture content limits have been waived. FIIN 926-3748 describes the same pallet as does FIIN 222-1053 except that softwood lumber has replaced hardwood lumber (table 1).

Only 14 of the 20 standard kinds of wooden pallets in existence in 1965 were purchased during that year. These 14 pallets are described by 6 different specifications; the 20 standard pallets are described by 9 different specifications. Three of the pallets — FIIN's 599-5326, 063-9075, and 141-7261 — accounted for 83.7 percent of the 1.36 million wooden pallets purchased. This seems

to indicate that some of the specifications and FIIN's are unnecessary.

Knocked-down pallets are covered by eight of the 20 FIIN's. Six of the eight are shipped in unit packages containing parts for 20 pallets, and two are shipped with parts for one pallet in each unit package. Practically all knocked-down pallets are sent overseas for assembly. DOD materials-handling experts believe that procurement of knocked-down pallets for domestic use can rarely be justified because machinery and labor costs of fabrication generally more than offset transportation savings. In 1965, 11.4 percent of all wooden pallets purchased by DGSC were knocked-down pallets (table 2). This percentage is very likely to increase as long as our overseas manpower commitments continue to increase.

Softwood pallets are covered by five of the 20 FIIN's; softwood-hardwood combination pallets are covered by two of the 20 FIIN's. In 1965, one-fourth of the wooden pallets purchased by DGSC were constructed of softwood lumber (table 2). This figure is slightly misleading because several of the specifications for softwood pallets include low-density broadleaf species, which are soft hardwoods.

Post pallets are described by only 3 of the 20 FIIN's. Yet, in 1965, about one-fourth of the wooden pallets purchased by DGSC were post pallets (tables 1 and 2). This proportion is not very likely to change appreciably unless the FIIN 141-7261 post pallet replaces the FIIN 599-5326 notched stringer pallet as the primary one for purchase and use within DOD. Otherwise the proportion is not very likely to increase because DOD contracting officers find it much more difficult to find suppliers of post pallets than stringer pallets and also because post pallets generally cost more initially than do stringer pallets of the same size.

Although only 12 of the 20 FIIN's describe wing pallets, more than 90 percent of the wooden pallets purchased by DGSC in 1965 were wing pallets (tables 1 and 2). Even though the wings are frequently damaged in warehouses, this percentage is expected to remain the same or increase because the probability is high that a DOD pallet will be loaded on a ship. Wings are

necessary on any pallet to be loaded on a ship using bar slings, which are fitted under the wings so that hoisting rigging may lift the unitized load from the pier up to the ship deck. This system needs to be studied from the standpoint of the economics of handling. Port officials believe that handling a 2,000-pound single-pallet load with a 20,000- to 50,000-ton capacity crane is much less efficient than using a special platform that will permit lifting two to six pallet loads at one time.

Plywood pallets have not been purchased as standard items by DOD to date. However, they are being evaluated by DOD, and some of the materials-handling experts in the Department anticipate using them in the near future.

Many different kinds of expendable pallets[4] have been tested and evaluated by DOD and are still under consideration for certain domestic shipping operations. However, past tests have shown that expendable pallets have limited applications because DOD must handle so many different varieties of goods (*15*).

PROCUREMENT

DOD wooden pallet procurement is a detailed process that requires considerable study by any firm wishing to sell profitably to DOD. We will not cover all the provisions associated with DOD procurement because many of the provisions are very detailed and, in several instances, apply only to rare aspects of procurement. Rather, we will discuss the general aspects of procurement plus those provisions that DGSC contracting officers have said are frequently misunderstood or misinterpreted by suppliers. DOD revises the provisions at frequent intervals; therefore, any firm planning to sell wooden pallets to DOD should carefully study written material received from DOD for changes in terms and conditions. Requests for clarification of the

[4] There is no clear definition of an expendable pallet. Some reusable pallets (pallets designed for many trips) are discarded after one trip, particularly for overseas shipments. Here, the term expendable refers to pallets that are designed for one trip only. Expendable pallets sell for about 40 percent of the selling price of reusable pallets and weight from 5 to 30 percent as much as reusable pallets.

Figure 1. — DGSC distribution areas in the United States.

terms and conditions should be directed to a contracting officer at DGSC.

Requisitions for standard wooden pallets needed at a DOD installation are channeled through one of the eight Defense Supply Agency (DSA) regional supply centers or depots[5] (see fig. 1 for the boundaries of the six supply areas served by the eight centers and depots) to the DGSC Directorate of Supply Operations (fig. 2, step 1). The DGSC Directorate of Supply Operations is responsible for seeing that the installation receives the pallets. Whenever possible, the pallets are transferred from another DOD installation that has a surplus of the pallets needed (fig. 2, step 2). If such a transfer is not possible, the requisition is sent to the DGSC Directorate of Procurement and Production so the pallets can be purchased (fig. 2, step 3). In 1965 and 1966, practically all pallet needs were met through purchase rather than transfer.

[5] Atlanta Army Depot, Forest Park, Ga.; Naval Supply Center, Norfolk, Va.; Naval Supply Center, Oakland, Calif.; Defense Depot Tracy, Tracy, Calif.; Defense Construction Supply Center, Columbus, Ohio; Defense Depot Memphis, Memphis, Tenn.; Defense General Supply Center, Richmond, Va.; and Defense Depot Ogden, Ogden, Utah.

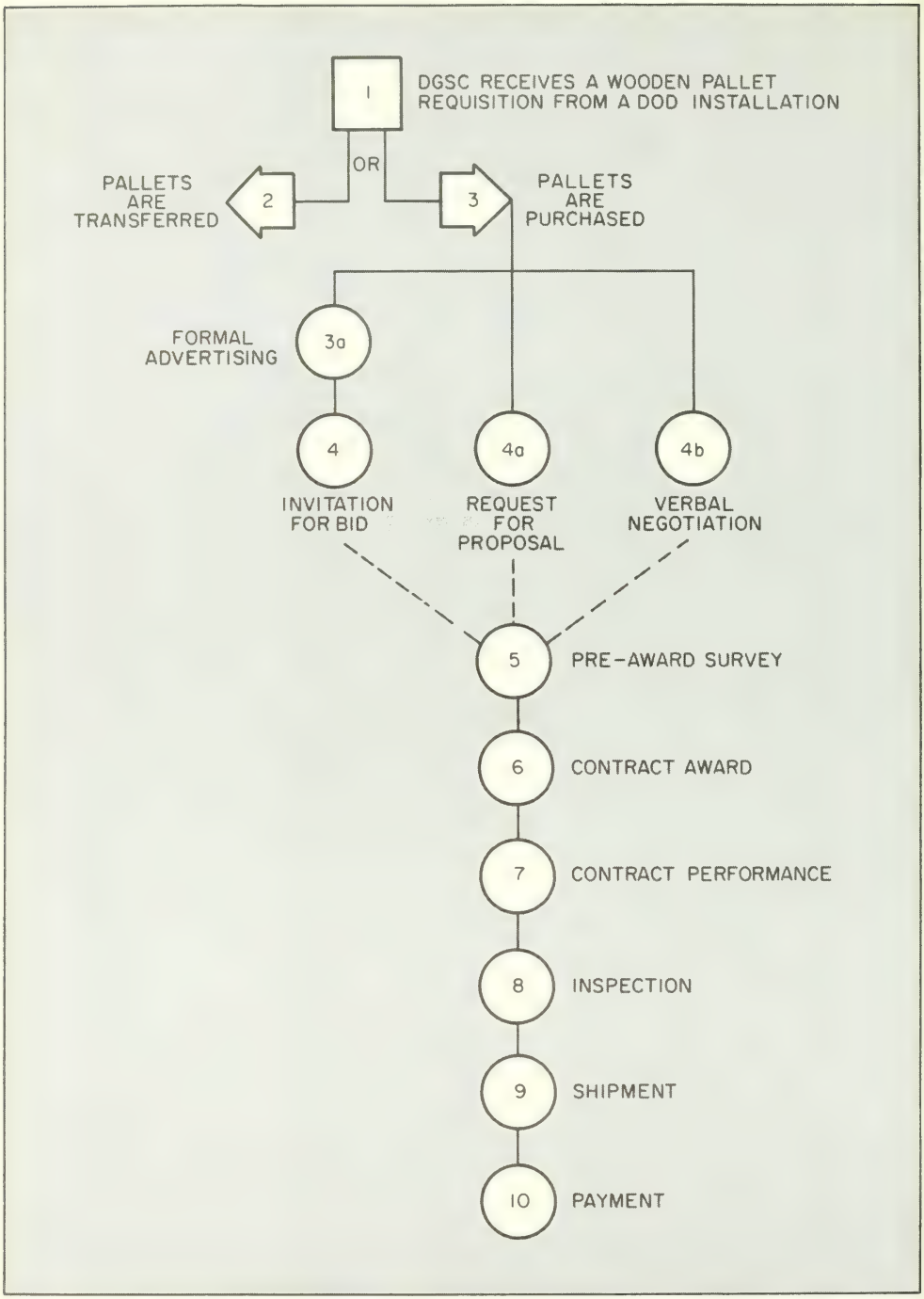

Figure 2. — DGSC wooden pallet procurement process.

The DGSC Directorate of Procurement and Production uses both competitive bidding and negotiation for purchasing wooden pallets. Competitive bidding is the normal procedure, and negotiation is used only under these circumstances:

- When requirements cannot be met through the normal bidding procedure.
- When the purchase is made during a period of declared national emergency.
- When the purchase amounts to less than $2,500.
- When the pallets will be procured and used outside the United States and its possessions.
- When the pallets will be used for experimental purposes.

Competitive Bidding

DGSC solicits bids by advertising and by sending invitation-for-bid forms to firms on its mailing lists[6] (fig. 2, steps 3a and 4). Advertisements are posted in the DGSC reception area and are summarized in the *Commerce Business Daily* — a U. S. Department of Commerce publication that lists proposed procurements exceeding $10,000. DGSC maintains one mailing list for hardwood pallets and one for softwood pallets. A potential supplier can submit an application for placement on either or both of the mailing lists. As of September 1966, there were 156 firms on the two mailing lists; only 20 to 30 were regular bidders.

All bid forms contain bidding instructions and the terms and conditions of purchase. The forms should be carefully and completely filled out or the bid may be disqualified.

Firms are normally allowed 20 to 30 days to prepare and submit bids. When a bid is accepted by DGSC it becomes a binding contract, and the supplier is legally bound to fulfill the conditions of the bid. Before accepting a bid, DGSC makes every effort to insure that the bid is realistic and that the firm is financially responsible. This is done because if a default occurs,

[6] Any wooden pallet producer or broker can obtain bid forms or applications for placement on the mailing lists by visiting the DGSC reception area or by writing to Commander, Defense General Supply Center, Attention: Directorate of Procurement and Production, Operations Support Office, Richmond, Va. 23219.

DGSC loses valuable time in obtaining the pallets, and the supplier may be forced to bear a large financial loss.

Even though an invitation for bid often calls for bids on orders of more than 100,000 pallets, any firm may bid on a portion of one order. In fact, it may be advantageous for a firm that has never supplied DOD pallets to bid on a small portion of an order to become familiar with DGSC procurement procedures. The bidder is responsible for specifying the portion of an order that he intends to supply.

Bid forms contain a clause that allows potential suppliers to bid f.o.b. origin and/or f.o.b. destination. A special condition of the bid forms, which is sometimes overlooked, is that when a shipping point and destination are in the same city (or county) the supplier must bear transportation costs to destination even though he may have bid f.o.b. origin.

Negotiation

Purchase by negotiation may employ written requests for proposals or verbal negotiation (fig. 2, steps 4a and 4b). In 1966, most pallets were purchased by requests for proposals because requirements could not be met through normal bidding procedures. Proposal request forms differ little from bid invitation forms and must be filled out in a similar manner. However, they are sent only to a sufficient number of reputable firms on the mailing lists to allow for receipt of competitive quotations.

Generally, verbal negotiation is used when requirements cannot be met through any other procedure.

Contract Awards

In addition to the administrative lead time required for advertising, preparing, and mailing invitations for bids or requests for proposals, and giving firms time to prepare and submit bids or proposals, DGSC requires 10 to 30 days to evaluate bids or proposals and to award contracts. DGSC tries to shorten administrative lead time as much as possible during periods of emergency demand as exists now because of the crisis in Southeast Asia.

Before an award is made, a DGSC contracting officer must decide whether the apparent low bidder (or offerer — one who submits a proposal rather than a bid) can meet contract terms and conditions. DGSC may desire additional information about the firm's technical, production, and financial capabilities before making a decision and may ask a specialist from the Defense Contract Administration Services to conduct a pre-award survey in those cases where it is considered necessary (fig. 2, step 5). This survey is conducted by a specialist who visits the firm and thoroughly investigates its technical, production, quality assurance, performances, and financial capabilities. If the pallets are needed immediately, the pre-award survey may be conducted by telephone or it may be omitted.

A contract is awarded to the firm (or firms) whose bid or proposal is most advantageous to DOD (fig. 2, step 6). All unsuccessful bidders or offerers are notified of the outcome several days after contracts are awarded. The name and bid or proposal price of the successful firm (or firms) may be obtained by visiting DGSC, by referring to the *Commerce Business Daily* (in the case of awards over $25,000), or by writing or calling a DGSC contracting officer.

DGSC enters into two types of contracts for wooden pallets: definitive contracts (fixed quantity and fixed price) or requirements contracts (open-end quantity and fixed price).

A definitive contract specifies the number of pallets that are to be supplied at the price submitted by the firm. DGSC may make an award on any portion or all of the quantity that the firm has indicated it can supply.

A requirements contract specifies the minimum quantity and the maximum quantity to be purchased at a set price during a specified time period. DGSC is obligated to place all orders for the contracted pallets with the firm that has been awarded the requirements contract. Exceptions to this obligation may be made for priority requirements that cannot be furnished by the firm within the delivery schedule of the contract, and for quantities that exceed the maximum order quantity of the contract if not acceptable to the firm.

In 1965, about three-fourths of the wooden pallets were purchased under definitive contracts and the remainder under requirements contracts. About 99 percent of wooden pallet purchases in 1966 were made under definitive contracts, probably because suppliers were reluctant to enter into requirements contracts because lumber prices changed significantly during the year.

Contracts are often set aside for firms in labor-surplus areas if efficient performance of the contract is possible at prices no higher than are obtainable elsewhere. Areas of "Substantial and Persistent Labor Surplus" and "Substantial Labor Surplus" are defined in the U. S. Department of Labor monthly publication *Area Trends in Employment and Unemployment.* If an area is not so defined, it may be individually certified by the Department of Labor. A prospective supplier can seek certification by contacting a local Department of Labor representative. In 1965, DGSC purchased one-third of its wooden pallets from firms in labor-surplus areas.

DGSC ordered wooden pallets from 40 different firms in 1965 (table 3). Seven firms supplied the majority of the pallets (50.3 percent); the largest supplier accounted for 14.6 percent.

More suppliers were located in California (23 percent) than in any other state mainly because many softwood pallets were required for overseas shipments from California ports. However, North Carolina firms supplied more pallets (22.2 percent) than did California firms (19.8 percent). Arkansas (16.8 percent) and Alabama (14.7 percent) were the other two states that supplied large volumes of pallets to DGSC (table 3). These figures do not mean that all the pallets were produced in the supplying states; some of the suppliers are brokers representing many producers in different states. Many of the manufacturing firms also sublet contracts or portions of contracts to producers in other states.

A potential supplier should not decide against submitting a bid or proposal only because the destination point for the pallets is a considerable distance from his shipping point. In 1965, some East Coast and Southern firms supplied pallets to DOD West Coast installations f.o.b. destination. If a supplier bids

f.o.b. destination for pallets that are requisitioned by an overseas installation, he is only responsible for paying for pallet transportation from the manufacturing site to the port from which the pallets will be exported.

CONTRACT PERFORMANCE

Contract performance includes fulfilling all requirements of a contract once an award has been made (fig. 2, step 7). After a contractor (pallet supplier) or a subcontractor receives a contract, he is required to send a Monthly Production Progress Report (DSA Form 375) each month to the administrative contracting officer at the Defense Contract Administration Services Region office designated on his contract. The contractor is also required to submit a Monthly Production Progress Report as soon as he becomes aware that there will be a delay in delivery — for example, delays caused by breakdown of equipment, late delivery of components, and catastrophes like storms or fires.

DGSC may terminate all or part of a contract by sending written notice of default to a contractor if the contractor fails to perform any provisions of the contract. If DGSC determines that contract termination resulted from fault or negligence on the part of a contractor or his subcontractors, the contractor must pay the difference between his bid or proposal price and the price at which the pallets were subsequently obtained. However, DGSC will not place a claim against the contractor if failure to perform was beyond his control or beyond control of his subcontractors — for example, if failure to perform resulted from a flood, fire, or labor strike.

A DGSC contracting officer may decide to terminate a contract in the best interest of DOD even though a contractor has fulfilled his part of the contractual agreement. When this happens, the DGSC contracting officer and the contractor must agree on payment for the contractors expenses incurred to the date of termination and also on how and where the pallets will be disposed of.

A DGSC contracting officer has the authority to decide the outcome of a contractual dispute whenever a contractor and DOD cannot arrive at an agreement suitable to both parties. If the contracting officer makes such a decision, he must furnish a written copy of the decision to the contractor. The contractor may appeal the contracting officer's decision in writing.

Inspection

Under DOD policies and procedures, the supplier is usually responsible for all inspections to insure that the pallets meet specifications (fig. 2, step 8). Supplier inspections may be waived under certain circumstances; DOD inspectors are then the sole judges of pallet quality and acceptability. The supplier must keep records of all his inspection work for the period of time stated in the contract. The DOD inspection requirements that must be met are stated in specifications, bid invitations, and proposal requests. Every supplier either must install an inspection system or have a system in use that meets DOD requirements. DOD helps suppliers set up an adequate inspection system. Some of the problems and difficulties relating to inspection result from inadequate quality-control systems; others result from misunderstandings between DOD and suppliers.

Even though pallets are inspected by the supplier, DOD reserves the right to perform a verification inspection for which the supplier must provide facilities and assistance needed. The extent of verification inspection is determined by the adequacy of the system used by the supplier.

A verification inspection is performed by quality assurance representatives of DOD and is based on a sample of pallets selected by random sampling from an order or shipment. An invitation for bid or request for proposal form specifies an Acceptable Quality Level (AQL) and an inspection level by specific statement or reference to applicable specifications. The DOD publication *Sampling Procedures and Tables for Inspection by Attributes* (MIL-STD-105D) contains tables that list the sample size and number of allowable defects for the given AQL

and inspection level. The quality of pallets in the sample must pass the AQL stated in the bid invitation or proposal request before the order is accepted. Failure to meet the quality standards of the specification may result in rejection of the order, reduction in price, or cancellation of the contract.

Shipment

Invitations for bids and requests for proposals usually contain all shipping instructions (fig. 2, step 9). The administrative contracting officer is responsible for providing any shipping information, including forms, that is not included in bid invitations or proposal requests. This information includes designation of the port of loading for overseas shipments.

When pallets will be shipped f.o.b. origin, the contractor must request three blank Request for Government Bills of Lading Forms from the administrative contracting officer designated on the contract. The contractor must fill out two copies of the request forms and send them to the administrative contracting officer at least 15 days before the pallets will be ready for loading in a rail car or motor vehicle. All f.o.b. origin shipments must be made in strict compliance with the Instructions for Processing U. S. Government Bill of Lading Forms, a form that is sent to the contractor along with the bill of lading. The carrier's representative must sign and date the Government Bill of Lading and send it, along with properly prepared invoices, to the administrative contracting officer as evidence that he has received the shipment.

At the time of each delivery under a specific contract, a Material Inspection and Receiving Report (DD Form 250) must be completed by the supplier and sent to the administrative contracting officer. The contractor is not supposed to ship any pallets until the Material Inspection and Receiving Report has been signed by an authorized DOD representative. The contractor may use part of the Material Inspection and Receiving Report as an invoice, or he may use a proper commercial invoice that includes contract number, order number, item number, contract description of pallets, sizes, quantities, unit prices, extended totals, dates

shipped and method of shipment; the bill of lading number and shipment weight must be shown on each shipment made on a Government Bill of Lading.

Unless advised otherwise by the administrative contracting officer, the contractor must make shipments in carload or truckload lots when the quantity to be delivered to any one destination constitutes a carload or truckload shipment. When an f.o.b. origin shipment to any one destination weighs less than 10,000 pounds, the administrative contracting officer may require the contractor to prepay the freight. When this is done, the contractor is reimbursed at a later date. For both f.o.b. origin and destination shipments, the contractor is responsible for seeing that pallets are loaded in the common carrier in accordance with published standards if they are available; otherwise the pallets must be loaded in a manner acceptable to the origin carrier. The contractor must pay for any damage to pallets in transit that results from improper loading, bracing, or blocking.

In 1965, 57.5 percent of all wooden pallets purchased by DGSC were shipped f.o.b. origin; the other 42.5 percent were shipped f.o.b. destination (table 4). About 93 percent of the knocked-down pallets and 54 percent of the assembled pallets were shipped f.o.b. origin. Two possible reasons why f.o.b. origin shipments prevailed for knocked-down pallets are: suppliers may have incorrectly assumed that on an f.o.b. destination order they would have to pay transportation costs to the overseas destination rather than to the domestic port of export, or DGSC may have usually solicited only f.o.b. origin bids or proposals for knocked-down pallets.

In 1965, three-fourths of the softwood pallets and more than one-fourth of the hardwood pallets purchased by DGSC were shipped f.o.b. destination. Possibly a greater proportion of softwood pallets were shipped f.o.b. destination because the shipping distance for softwood pallets is often much shorter and there are fewer destination points than for hardwood pallets. California firms supplied 80 percent of the softwood pallets and generally sent them to the Tracy Defense Depot or the Oakland Naval Supply Center. This simpler distribution system for softwood

pallets may allow softwood pallet suppliers to become more familiar with economical routes and transportation rates.

Payment

The contractor is paid after DGSC receives certification that the pallets have been accepted at the delivery point (or points) stated in the contract (fig. 2, step 10). Payment for partial deliveries may be made when requested by the contractor if such payment equals or exceeds either $1,000 or 50 percent of the total amount of the contract.

Payment is more prompt for pallets supplied f.o.b. origin than for those supplied f.o.b. destination. Payment for f.o.b. origin shipments is processed when the administrative contracting officer receives evidence that the pallets have been placed in a common carrier, but payment for f.o.b. destination shipments is not processed until the administrative contracting officer receives evidence that the pallets have arrived undamaged at the destination point. From 1962 through 1965, 72 percent of the wooden pallets bought by DGSC were bought f.o.b. origin. The yearly percentage of f.o.b. origin purchases in 1962-65 ranged from a high of 91 percent in 1964 to a low of 57 percent in 1965 (table 5). Possible reasons for the sharp drop in f.o.b. origin purchases in 1965 are:

- There was substantially more direct pallet delivery in 1965 than in any of the preceding 3 years; i.e., DGSC knew the specific destinations when bids were invited or proposals were requested. Before 1965, DGSC commonly listed tentative destinations for f.o.b. destination bids, mainly to determine whether firms could obtain better freight rates than DGSC could obtain.
- There were more high-priority orders in 1965 than in any of the preceding 3 years. When pallets are needed on relatively short notice, purchases are often restricted to f.o.b. destination so DGSC will not have to obtain and compare freight rates when evaluating bid or proposal prices.

Prices paid by DGSC for most wooden pallets that were purchased f.o.b. origin[7] increased moderately from 1962 to 1965; some of the prices actually decreased during the 4-year period

[7] F.o.b. destination shipments were not considered in computing average prices because the percent of transportation costs in pallet prices is difficult to determine.

(table 6). Average prices of four of the five main kinds of pallets purchased by DGSC increased from 12.8 to 50.6 percent during the period. The average price of the other main pallet, which is the only softwood pallet in the main group, decreased 0.5 percent (table 8). Pallet price probably will increase more from 1965 to 1966 than for any other comparable period since 1962 because the price of pallet lumber increased substantially in 1966.

Average prices of two of the three softwood pallets purchased f.o.b. origin in 1962-65 decreased; the average price of the third increased only 10 percent. On the other hand, average prices of 9 of the 11 hardwood pallets purchased f.o.b. origin during the period increased (table 6). The difference between price changes of hardwood and softwood pallets can be accounted for mainly by the fact that hardwood lumber prices increased about 10 percent more than did softwood lumber prices during this same period.[8]

The percentage range from the low to high f.o.b. origin price (based on the low price) paid for a specific pallet in 1965 varied from 0 to 78 percent (table 7). Four of the six knocked-down pallets bought f.o.b. origin in 1965 varied more in price than any of the six assembled pallets bought that year. The greater price variation for the knocked-down pallets is probably due to the limited experience that most pallet firms have in producing these units; the firms are less familiar with controlling production costs of knocked-down pallets than of assembled pallets.

There did not appear to be any trend toward lower prices as order size increased during 1965. In fact, many of the prices increased as order size increased. The increasing price-increasing order size relationship may be explained by two factors: (1) competition probably decreases as order size increases because many small firms will not bid on large orders because they believe they must supply the entire order (in most instances they can state the portion of the order they wish to supply), and (2) some firms capable of supplying large quantities of pallets were not

[8] U.S. Department of Labor. Prices and price indexes: group 8 — lumber and wood products. 1962, 1963, 1964, and 1965.

particularly anxious to obtain a contract but merely wished to remain on a mailing list and submitted bids much higher than normal. Some of these bids were accepted because demand increased during the year.

In 1965 the prices of most of the pallets increased as the year progressed (table 8). Average prices of 8 of the 12 pallets bought f.o.b. origin in 1965 were the same or higher for the fourth quarter of the year than for the entire year (table 8). Average prices of four of the five main kinds of pallets purchased by DGSC increased from 5 to 42 percent from the third to fourth quarter. The average price of the other pallet, which is the only softwood one in the main group, decreased 1 percent from the third to fourth quarter.

Average prices of pallets supplied from the south central (Memphis) and northeastern (Richmond) areas of the United States generally were lower than average prices of those supplied from other areas (table 9, and fig. 1).

WHERE AND WHEN PALLETS ARE NEEDED

In 1965, 89.8 percent of the wooden pallets purchased by DGSC were bought for destination points in the continental United States (CONUS). Goods for overseas shipment were placed on many of the pallets when the pallets arrived at CONUS destination points. The remaining 10.2 percent of the pallets were sent directly to non-CONUS destinations, where goods were placed on them. Most of the pallets bought for CONUS destinations went to California (43.9 percent) and Virginia (14.0 percent) (table 10). These two states were the main destination points for wooden pallets because most overseas shipments of palletized DOD goods leave the United States from DOD depots and supply centers in California and Virginia.

In 1965, DGSC received requisitions for 1,609,384 wooden pallets from DOD. DGSC purchased 1,360,075 wooden pallets in 1965. The number of wooden pallets purchased is less than the requisitioned quantity because some of the requisitioned

quantity was obtained by transfer from other depots or by DGSC purchase in 1966.

The Armed Forces needed 79.8 percent of the wooden pallets bought by DGSC in 1965. Most of the wooden pallets were needed by the U. S. Army (39.2 percent) and the U. S. Navy (37.0 percent). Other sources of demand — the Coast Guard, General Services Administration, and the Military Assistance Program — needed 20.2 percent of the pallets (table 11).

In 1965, DGSC received requisitions for 76.0 percent of the wooden pallets during the last half of the year. This increase in demand was primarily attributable to the increase in manpower commitments to Southeast Asia. More pallets were requisitioned in November (21.0 percent) than in any other month (table 12). More pallets were requisitioned in June (9.5 percent) than in any other of the first 6 months. This was probably because requisitions of items that are always needed are often made near the end of DOD's fiscal year (July 1 - June 30).

Western installations (Tracy area — fig. 1) requisitioned 51.1 percent of all pallets requisitioned in 1965. The Tracy Defense Depot required 33.5 percent, and the Oakland Navy Supply Center required 17.5 percent. Installations in the Richmond area (fig. 1) requisitioned the next greatest volume of pallets — 18.9 percent (table 13).

Most knocked-down and softwood pallets are shipped overseas — 81.6 percent of the knocked-down pallets and 83.4 percent of the softwood pallets were requisitioned by either the Tracy or Richmond areas (table 13, fig. 1). These high percentages are not unexpected because most overseas shipments originate in California and Virginia.

PROBLEMS

DGSC found it increasingly difficult to obtain pallets constructed of seasoned hardwood lumber in the last few months of 1965 and during most of 1966. Consequently, three new FIIN's were assigned to wooden pallets — two for pallets made of

unseasoned hardwood lumber and one for a pallet made of softwood lumber.

Why was it difficult for DGSC to buy the kinds of pallets needed? First, hardwood lumber generally — and seasoned hardwood lumber specifically — was scarce; and second, many firms did not submit bids or proposals. During the last half of 1966, lumber shortages became less pronounced.

Some of the possible reasons why firms will not consider supplying pallets to DOD are:

DOD pallet demand generally fluctuates more than private industrial pallet demand. — Many firms do not want to become dependent on DOD as a customer because of the irregular nature of DOD demand due to the variability in degree of armament and the periodic availability of funds. Since private industrial demand for wooden pallets is increasing at a rapid rate, many firms find it difficult even to supply regular customers with whom they have a close marketing relationship. Therefore, they do not want to supply DOD if doing so would mean that shipments to the regular private industrial customers would be decreased or delayed. Many of the pallet firms cannot or do not want to expand production in order to supply DGSC because (1) additional labor and/or capital are not available, (2) production lines will be inefficient if the DOD pallets are significantly different from the industrial pallets being constructed, and (3) there is a risk that investing in expanded production capacity will become excess capacity if a sudden and large decrease in DOD pallet demand occurs.

Perhaps some provisions could be made to inform pallet firms periodically of future DOD pallet needs. A printed forecast for pallets needed from July 1, 1966 to June 30, 1967 was sent by DGSC to pallet firms on February 4, 1966. Because requirements change rapidly, forecasts should be published at least every 6 months.

DOD wooden pallet specifications are more detailed and complicated than most private industrial specifications. — DOD is making an effort to improve specifications by attaching an analysis sheet to many of the specifications. Anyone who has criticisms of

the specifications and suggestions for improvement is asked to fill out the analysis sheet, but DOD officials have stated that few of these sheets are returned. Some specific steps that DOD could take to make the specifications more understandable are:

1. Enlarge and clarify the print. — On some copies of the specifications the verbal descriptions and diagrams are almost unreadable even through a magnifying glass.
2. Standardize references to wood species. — Some pallets classified as "softwood" by DOD may actually be constructed of low-density broadleaf species (hardwoods), and species allowed vary considerably among specifications. Less confusion would likely result if all specification references to species were changed to conform with the National Wooden Pallet and Container Association pallet lumber species groups based on density classes, which are widely employed for industrial pallets. Standardization of species would eliminate much confusion among pallet suppliers and would simplify pallet inspection. It would permit designation in the specifications by species groups instead of by separate species lists.
3. Standardize references to wood quality and nailing requirements. — References to wood quality and nailing requirements vary considerably among DOD pallet specifications and between some of the DOD pallet specifications and the DOD specifications for wood quality (MIL-STD-731) and nails (FF-N-105a). With minor revisions, MIL-STD-731 and FF-N-105a would describe wood quality and nails for all DOD wooden pallets. Then pertinent extracts from MIL-STD-731 and FF-N-105a could be included in the individual pallet specifications. Another method of standardization would be for DOD to adopt the wood-quality and nailing requirements of the National Wooden Pallet and Container Association, if these are found suitable for DOD purposes.
4. Standardize the format and terminology of the specifications. — Format and terminology also vary considerably among specifications (table 14). If format and terminology were standardized among DOD pallet specifications or if the National Wooden Pallet and Container Association specification format

and terminology could be adopted, suppliers would understand DOD requirements more easily.

DOD pallet inspections are more strict than most private industrial inspections. — Several firms have indicated that they are reluctant to supply DOD pallets mainly because they are concerned about the practical difficulties of meeting DOD's inspection requirements. According to DOD policy, the extent of verification inspection performed by a DOD inspector depends on the accuracy of the inspection system used by the firm. However, even the largest and most efficient pallet suppliers are subject to a verification inspection at their plant for all orders exceeding $2,500. Pallets supplied by firms that have previously sold high-quality pallets to DOD are usually spot-inspected; i.e., not all shipments are inspected by a DOD inspector. If past experience has indicated to DOD that verification inspections (or regular DOD inspections when supplier inspections are waived) are necessary, DOD could make these inspections less objectionable to the suppliers by:

1. Making sure the pallets are inspected when they are ready for shipment. — Some suppliers complain that shipments are delayed and pallets take up valuable storage space because an inspector is not available.
2. Making sure the inspectors are familiar with pallets. — The time needed for inspection is increased significantly if the inspector is unfamiliar with pallet characteristics and specifications.

DOD has taken steps to improve inspection procedures, but continuing effort will be required.

DOD payment for pallets sometimes takes longer than private industrial payment. — DOD could probably obtain additional sources of supply by speeding up payment.

DOD transactions require more forms that are in greater detail than do most private industrial transactions. — DOD could help the suppliers by reducing the number of copies of various forms needed for a transaction and by handling chores like photocopying. Many pallet firms have no equipment for these jobs and must go to great trouble to have such work done.

Regardless of procedures adopted to help firms supply wooden pallets, DOD occasionally will be confronted with procurement problems whenever competitive bidding is used as a purchasing tool. DOD officials complain that pallets supplied by some low bidders are inferior in quality to those supplied by reputable firms that previously have sold high-quality pallets to DOD. And, although firms have passed the requirements of a pre-award survey, they sometimes default because raw materials, capital, or business skill are inadequate. These difficulties are common to all standard government procurement procedures, and to some extent are unavoidable because the government must establish controls to insure that it obtains the best value. But procurement problems associated with competitive bidding might be eased if DOD (1) conducted more thorough pre-award surveys, (2) periodically checked firms that passed surveys to make sure the firms were maintaining acceptable production and financial standards, and (3) placed more emphasis on factors other than price when awarding contracts.

THE FUTURE

An accurate forecast of future DOD demand for wooden pallets is difficult to make because requirements and policies change rapidly. For example, in February 1966 DGSC estimated that purchases of five of the main kinds of pallets required[9] in fiscal year 1967 (July 1, 1966 - June 30, 1967) would total 2,445,464 pallets. By August 1966 the estimate had been changed to 3,189,799 pallets.

In December 1966, DOD began to use plywood containers mounted on skids in place of pallets to ship goods to Southeast Asia. This change was made because exposure to bad weather damaged goods, and unit loads on pallets were subject to pilfering. This trend toward containerization will probably lower the demand for some of the kinds of pallets listed in table 1.

Aside from shipping changes such as the use of plywood con-

[9] FIIN's 063-9075, 141-7261, 223-6529, 291-8717, and 599-5326.

tainers, demand during the next several years for the kinds of pallets listed in table 1 will probably containue to be influenced mainly by the degree of armament and availability of funds. As of January 1967, there were about 400,000 DOD personnel in Vietnam. Defense Secretary McNamara, as quoted in the *Wall Street Journal* of January 26, 1967, estimated that troop buildup in Vietnam would continue for the next 18 months. As long as so many U. S. personnel are in Vietnam, pallet (and plywood container) demand will remain at a high level because it has been estimated that a soldier uses 35 pounds of food, clothing, ammunition, and PX supplies per day (*1*). If we assume that 2,000 pounds of goods are on each pallet (or in each plywood container), 7,000 pallet loads are needed per day. None of the pallets sent to Vietnam are returned to the United States (some of the plywood containers are returned). As long as so many pallets (and plywood containers) are needed for Vietnam, the greatest demand for wooden pallets probably will continue to be in the Tracy and Richmond distribution areas (fig. 1).

In the near future, a greater proportion of DOD wooden pallet demand will very likely be accounted for by the indirect market segment because DOD is trying to buy more goods on pallets from private industrial firms. Under present policy the firms would be responsible for purchasing pallets that meet DOD specifications; however, the Defense Personnel Support Center in Philadelphia, Pa., which is responsible for procuring subsistence items, has requested that DGSC begin purchasing pallets for these private industrial firms in the near future because firms often find it difficult to obtain small quantities of wooden pallets that conform to DOD specifications.

DOD has made or is considering some changes in materials-handling techniques that will appreciably affect future demand for pallets. These changes are being considered because at times DOD contracting officers have found it difficult to purchase the kinds and quantities of wooden pallets needed and because some DOD experts believe that materials-handling systems utilizing non-wooden pallets or no pallets would be more efficient than the system utilizing wooden pallets. These changes are:

Specification modifications. — New FIIN's have been assigned to pallets fabricated of unseasoned lumber. However, DOD materials-handling experts believe that pallets constructed of seasoned lumber have longer life, offer greater resistance to damage, and are more economical than pallets constructed of unseasoned lumber. Therefore, the waiver of moisture-content limits is a temporary measure, which probably will be repealed when and if an ample supply of seasoned lumber becomes available. Fewer or smaller nails also have been approved for some pallets, and changes in the packing requirements for shipment of both assembled (10 pallets will be strapped together) and knocked-down pallets are being implemented. Possibly chamfering requirements for bottom deckboards will be removed from the specifications. The only other specification changes being planned for the near future are consolidation of some of the specifications already being used.

Utilization of sources of supply outside the United States. — Bids were requested from Canadian firms for the first time in the spring of 1966. The Buy-American Act (41 U. S. Code a-d) provision in wooden pallet contracts stipulates that preference be given to domestically manufactured pallets.[10] This clause may be waived under these circumstances:

1. When the pallets are for use outside the United States.
2. When the Government determines that sufficient and reasonably available quantities of acceptable pallets are not manufactured in the United States.
3. When the Secretary of Defense determines that the preference for domestic products is inconsistent with the public interest; for example, when pallet cost is determined to be unreasonable.

Implementation of production and price controls. — For the first time since the Korean War, DOD has ordered manufacturers of certain goods to turn out defense materials; wooden pallets may be procured in this manner also if conditions warrant.

Utilization of non-lumber pallets. — Metal pallets are now being used by DOD; and plastic, plywood, fiberboard, and other

[10] For classification as a domestically manufactured pallet, the cost of the pallet components produced or manufactured in the United States or Canada must exceed 50 percent of the costs of all the pallet components.

materials have been tested as pallet components in DOD laboratories. High costs have prevented the purchase of non-lumber pallets for most DOD materials-handling operations. However, during the first part of 1966, the initial cost of lumber pallets and other wood products increased appreciably. This cost increase prompted DOD to make a concerted and immediate effort to determine and specify substitute materials whenever economically justifiable.

Utilization of palletless materials-handling systems. — In 1963 the U. S. Navy studied an integrated material-movement system with the objective of integrating all the systems for moving materials within DOD and between DOD and suppliers. One of the important features of the system was that it would revolve around a unit load handled without a pallet. An excerpt from a magazine article (8) pertaining to the research explains the Navy's reasoning:

> Constant research and development . . . benefits industrial shippers with improved pallets today and the prospect of new handling systems for tomorrow . . . Navy has decided that it had gone just about as far with pallets as it can. Not that it will cease using pallets overnight or that it will abandon its pallet-testing program. Far from it. But like industry, the military must always be one jump ahead of today . . . With the large cost of pallet replacement to be faced each year by the Navy, the idea of doing without pallets at all has great appeal. This is true not only for the Navy but for all services.

Although this study has been ended, DOD materials-handling experts are still considering the use of palletless systems for specific handling operations.

The real economies in the use of pallets have not been considered by DOD. In the realm of modern materials-handling, the concept of each individual firm or agency functioning independently of all others is rapidly becoming archaic. DOD as well as industry has the key to very sharply reduced distribution costs far in excess of the potential savings from other systems. Pallet-exchange programs can and must be developed between DOD and industry. Even though pallets now pay for themselves through savings 3 to 5 times, under exchange programs they can return 15 to 20 times their cost.

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Table 1.—*Standard DOD wooden pallets*

Federal Item Identification number (FIIN)[1]	Specification or purchase description number	Assembled (A) or knocked-down (Kd)[2]	Type of lumber[3]	Dimensions (inches)	Number and type of deck supports	Entry	Sides
063-9075*	NN-P-71b	A	Softwood	40X48	3 stringers	2-way	Double wing
063-9076	NN-P-71b	A	Hardwood	40X48	3 stringers	2-way	Double wing
141-7237	MIL-P-26966C	A	Softwood	40X48	9 posts	4-way	Flush
141-7261*	MIL-P-15011E	A	Hardwood	40X48	9 posts	4-way	Double wing
141-7262	MIL-P-4894	A	Softwood	40X48	3 stringers	2-way	Flush
202-2217	MIL-P-15943B	A	Hardwood	48X72	3 stringers	2-way	Double wing
222-1044	NN-P-71b	A	Hardwood	48X60	5 stringers	2-way	Flush
222-1046	NN-P-71b	A	Hardwood	32X40	3 stringers	2-way	Flush
222-1048	NN-P-71b	Kd	Hardwood	32X40	3 stringers	2-way	Flush
222-1051	NN-P-71b	Kd	Hardwood	48X60	5 stringers	2-way	Flush
222-1053	MIL-P-15943B	Kd	Hardwood	48X72	3 stringers	2-way	Double wing

223-6529*	MIL-P-15011E	Kd	Hardwood	40X48	9 posts	4-way	Double wing
291-8717*	NN-P-71b	Kd	Hardwood	40X48	3 stringers	2-way	Flush
542-3294	MIL-P-22562	A	Hardwood	32X40	3 notched stringers	Partial 4-way	Double wing
555-0458	NN-P-71b	A	Hardwood	40X48	3 stringers	2-way	Flush
599-5326*	MIL-P-3938B	A	Hardwood	40X48	4 notched stringers	Partial 4-way	Double wing
892-4394	USA TRECOM-PD-14	Kd	Softwood	57X32¼	3 notched stringers	Partial 4-way	Double wing
892-4395	USA TRECOM-PD-14	Kd	Softwood	44X31⅜	3 notched stringers	Partial 4-way	Double wing
955-9632	USA MO(AVSCOM) PD-367A	A	Hardwood and Softwood	48X72	3 stringers	2-way	Double wing
956-2950	USA MO(AVSCOM) PD-367A	Kd	Hardwood and Softwood	48X72	3 stringers	2-way	Double wing

[1] The five kinds of pallets designated by an asterisk (*) beside the FIIN's constituted 91 percent of the purchases in 1965 and probably a greater percentage in 1967.

[2] The knocked-down category refers to parts for pallets that are packaged for shipment to a DOD installation, generally overseas, where fabrication takes place. All but two are shipped in bundles containing parts for 20 pallets; FIIN's 222-1053 and 956-2950 require parts bundled for one pallet only.

[3] Some DOD specifications and purchase descriptions allow only certain species for pallet construction — in several instances, low-density broadleaf species are classified as "softwoods."

Table 2.—*Wooden pallets purchased by DGSC in 1965, by Federal Item Identification Number*

(Numbers in boldface indicate knocked-down pallets)

Federal Item Identification Number (FIIN)[1]	Number of pallets	Percent
599-5326*	576,782	42.41
†063-9075*	321,061	23.60
141-7261*	240,628	17.69
223-6529*	71,560	5.26
222-1051	32,940	2.42
291-8717*	24,720	1.82
555-0458	23,053	1.69
222-1046	21,282	1.56
202-2217	18,844	1.39
†892-4395	11,100	.82
†892-4394	10,000	.74
222-1053	3,225	.24
†141-7237	3,100	.23
222-1048	1,780	.13
All pallets	1,360,075	100.00

[1] See table 1 for descriptions of the pallets.
* Primary kinds of pallets to be purchased by DGSC in the near future.
† Softwood pallets.

Table 3.—*Wooden pallets supplied in 1965, by states and firms*

State	Number of firms	Number of pallets	Percent of pallets
North Carolina	5	302,427	22.24
California	9	269,476	19.81
Arkansas	5	227,912	16.76
Alabama	3	199,514	14.67
Mississippi	2	69,690	5.12
Colorado	1	64,340	4.73
Maryland	1	48,632	3.58
New Jersey	1	38,604	2.84
Virginia	3	35,541	2.61
Tennessee	3	27,800	2.04
Oregon	1	21,721	1.60
Washington	1	20,000	1.47
South Carolina	1	15,800	1.16
Ohio	1	8,401	.62
Georgia	1	4,981	.37
Texas	1	4,380	.32
Michigan	1	856	.06
Total	40	1,360,075	100.00

Table 4.—*Wooden pallets purchased by DGSC in 1965, by type of shipment and Federal Item Identification Number*

(Numbers in boldface indicate knocked-down pallets)

Federal Item Identification Number (FIIN)[1]	F.o.b. origin		F.o.b. destination		Total pallets purchased
	Number	*Percent*	*Number*	*Percent*	*Number*
599-5326*	354,478	61.46	222,304	38.54	576,782
†063-9075*	81,018	25.23	240,043	74.77	321,061
141-7261*	175,297	72.85	65,331	27.15	240,628
223-6529*	71,420	99.80	140	.20	71,560
222-1051	31,940	96.96	1,000	3.04	32,940
291-8717*	24,720	100.00	0	0	24,720
555-0458	9,000	39.04	14,053	60.96	23,053
222-1046	12,206	57.35	9,076	42.65	21,282
202-2217	13,422	71.23	5,422	28.77	18,844
†892-4395	3,660	32.97	7,440	67.03	11,100
†892-4394	0	0	10,000	100.00	10,000
222-1053	2,646	82.05	579	17.95	3,225
†141-7237	**0**	0	3,100	100.00	3,100
222-1048	1,660	93.26	120	6.74	1,780
All FIINs	781,467	57.46	578,608	42.54	1,360,075

[1] See table 1 for descriptions of the pallets.

* Primary kinds of pallets to be purchased by DGSC in the near future.

† Softwood pallets.

Table 5.—*Wooden pallets supplied from 1962 to 1965, by type of shipment*

Year	F.o.b. origin		F.o.b. destination		Total pallets supplied
	Number	*Percent*	*Number*	*Percent*	*Number*
1962	612,593	81.62	137,972	18.38	750,565
1963	430,675	70.35	181,510	29.65	612,185
1964	571,627	91.49	53,141	8.51	624,768
1965	781,467	57.46	578,608	42.54	1,360,075
All years	2,396,362	71.58	951,231	28.42	3,347,593

Table 6.—*Average f.o.b. origin wooden pallet prices, 1962-1965, by Federal Item Identification Number*

(Numbers in boldface indicate knocked-down pallets)

Federal Item Identification Number (FIIN)[1]	1962	1963	1964	1965	Change in price 1962-65
					Percent
†063-9075*	$ 2.07	$ 2.09	(2)	$ 2.06	−0.5
063-9076	1.82	(3)	(3)	(2)	—
†141-7237	2.43	2.08	$ 2.00	(3)	—
141-7261*	2.79	2.83	2.94	3.23	+13.6
†141-7262	(2)	(2)	(2)	(2)	—
202-2217	14.90	9.95	9.68	9.86	−33.8
222-1044	(2)	(2)	(2)	(2)	—
222-1046	1.77	1.83	1.91	1.88	+6.2
222-1048	2.00	2.10	1.97	2.20	+10.0
222-1051	3.36	3.85	4.35	4.61	+37.2
222-1053	(2)	10.50	11.69	12.25	—
223-6529*	3.04	3.05	2.88	4.58	+50.6
291-8717*	2.26	2.37	2.77	2.55	+12.8
542-3294	1.81	1.97	2.08	(2)	—
555-0458	2.57	2.54	2.41	2.55	−.8
599-5326*	2.65	2.85	2.88	3.16	+19.2
†892-4394	(2)	(2)	(2)	(3)	—
†892-4395	2.29	(2)	(3)	2.52	+10.0
955-9632	(2)	(2)	(2)	(2)	—
956-2950	(2)	(2)	(2)	(2)	—

[1] See table 1 for descriptions of the pallets.
[2] No pallets were purchased.
[3] All pallets were purchased f.o.b. destination.
† Softwood pallets.
* The primary kinds of pallets to be purchased by DGSC in the near future.

Table 7.—*F.o.b. origin wooden pallet prices, 1965, by Federal Item Identification Number*

(Numbers in boldface indicate knocked-down pallets)

Federal Item Identification Number (FIIN)[1]	Average price	Price range	Price range
			Percent
†063-9075*	$ 2.06	$ 2.05- 2.30	12.2
141-7261*	3.23	2.84- 4.50	58.4
202-2217	9.86	9.10-11.50	26.4
222-1046	1.88	1.84- 2.04	10.9
222-1048	2.20	2.20- 2.20	0
222-1051	4.61	3.57- 6.14	72.0
222-1053	12.25	10.38-18.50	78.2
223-6529*	4.58	2.92- 4.95	69.5
291-8717*	2.55	2.45- 4.19	71.0
555-0458	2.55	2.55- 2.55	0
599-5326*	3.16	2.73- 3.78	38.5
†**892-4395**	2.52	2.50- 2.79	11.6

[1] See table 1 for descriptions of the pallets. All pallets conforming to FIIN's 141-7237 and 892-4394 were purchased f.o.b. destination.

† Softwood pallets.

* The primary kinds of pallets to be purchased by DGSC in the near future.

Table 8.—*Average f.o.b. origin wooden pallet prices, 1965, by quarter of the year and Federal Item Identification Number*

(Numbers in boldface indicate knocked-down pallets)

Federal Item Identification Number (FIIN)[1]	1 Jan.- Mar.	2 Apr.- June	3 July- Sept.	4 Oct.- Dec.	Average
†063-9075*	—	—	$ 2.07	$ 2.05	$ 2.06
141-7261*	—	$ 2.89	3.25	3.41	3.23
202-2217	$ 9.44	9.40	9.67	10.48	9.86
222-1046	1.85	—	1.88	1.88	1.88
222-1048	—	—	—	2.20	2.20
222-1051	3.85	—	3.57	3.63	4.61
222-1053	—	10.38	11.83	14.31	12.25
223-6529*	3.05	—	3.29	4.67	4.58
291-8717*	—	—	2.45	2.69	2.55
555-0458	—	—	2.55	—	2.55
599-5326*	—	2.83	3.11	3.36	3.16
†**892-4395**	—	—	2.79	2.50	2.52

[1] See table 1 for descriptions of the pallets. All pallets conforming to FIIN's 141-7237 and 892-4394 were purchased f.o.b. destination.

† Softwood pallets.

* Primary kinds of pallets to be purchased by DGSC in the near future.

Table 9.--*Average f.o.b. origin wooden pallet prices, 1965, by geographical region of the suppliers and Federal Item Identification Number*

(Numbers in boldface indicate knocked-down pallets)

Federal Item Identification Number (FIIN)[1]	Region[2]						Average
	Richmond	Atlanta	Memphis	Columbus	Ogden	Tracy	
†063-9075*	—	—	—	—	—	$ 2.06	$ 2.06
141-7261*	$ 2.96	$ 3.98	$ 3.05	$ 3.75	—	—	3.23
202-2217	10.05	—	9.10	11.50	—	—	9.86
222-1046	1.91	1.84	1.86	—	—	—	1.88
222-1048	—	2.20	—	—	—	—	2.20
222-1051	5.35	5.98	3.64	—	—	—	4.61
222-1053	11.92	14.00	—	—	—	—	12.25
223-6529*	3.82	3.61	2.92	—	$ 4.95	—	4.58
291-8717*	—	2.46	—	—	4.19	—	2.55
555-0458	—	—	2.55	—	—	—	2.55
599-5326*	2.96	3.46	3.16	—	—	—	3.16
†892-4395	2.50	2.79	—	—	—	—	2.52

[1] See table 1 for descriptions of the pallets. All pallets conforming to FIIN's 141-7237 and 892-4394 were purchased f.o.b. destination.

[2] See figure 1 for the regional boundaries.

† Softwood pallets.

* The primary kinds of pallets to be purchased by DGSC in the near future.

Table 10.—*Wooden pallet primary destination points in 1965*

Primary destination point	Number of pallets	Percent
Total	1,360,075	100.00
CONUS[1] destinations	1,220,677	89.75
California	597,094	43.90
Virginia	190,327	13.99
Tennessee	89,211	6.56
Utah	80,540	5.92
Pennsylvania	54,786	4.03
Ohio	37,792	2.78
Georgia	33,396	2.46
Oklahoma	20,248	1.49
Texas	19,746	1.45
Washington	14,814	1.09
Indiana	10,484	.77
New York	10,118	.74
Oregon	7,700	.57
Alabama	7,034	.52
North Carolina	6,750	.50
Illinois	6,500	.48
Kentucky	5,500	.40
Colorado	5,350	.39
Nevada	5,000	.37
Louisiana	2,681	.20
Kansas	2,550	.19
District of Columbia	2,550	.19
Montana	2,000	.15

CONTINUED

Table 10—Continued

Primary destination point	Number of pallets	Percent
Rhode Island	2,000	.15
Massachusetts	1,725	.13
Missouri	1,500	.11
Florida	1,300	.09
Arizona	1,031	.08
Connecticut	350	.02
Arkansas	200	.01
Maryland	200	.01
New Mexico	200	.01
Non-CONUS destinations	139,398	10.25
Okinawa	58,049	4.27
France	32,400	2.38
Hawaii	16,676	1.23
Vietnam	13,000	.95
Germany	7,740	.57
Korea	7,552	.56
Canal Zone	1,300	.09
Puerto Rico	629	.05
Dominican Republic	500	.04
Bermuda	400	.03
Spain	279	.02
Libya	158	.01
Japan	118	.01
Taiwan	100	.01
England	50	—
Canada	47	—
Unknown	400	.03

[1] Continental United States.

Table 11.—*Wooden pallet demand in 1965, by service branch and Federal Item Identification Number*

(Numbers in boldface indicate knocked-down pallets)

Federal Item Identification Number (FIIN)[1]	Army	Navy	Air Force	Marine Corps	Other[2]	Total	Percent
†063-9075*	37,918	155,761	—	—	108,457	302,136	18.78
063-9076	2,500	500	—	—	—	3,000	.19
†141-7237	—	3,000	3,950	—	—	6,950	.43
141-7261*	181,917	96,899	32,053	—	163,027	473,896	29.45
202-2217	11,541	5,666	873	—	—	18,080	1.12
222-1044	23,232	1,000	200	—	—	24,432	1.52
222-1046	24,815	—	1,100	—	200	26,115	1.62
222-1048	4,480	—	—	—	—	4,480	.28
222-1051	28,660	—	—	—	—	28,660	1.78
222-1053	1,005	—	158	—	—	1,163	.07
223-6529*	68,000	—	500	—	—	68,500	4.26
291-8717*	91,260	—	2,100	—	—	93,360	5.80
542-3294	—	200	1	—	—	201	.01
555-0458	24,639	—	200	—	—	24,839	1.54
599-5326*	60,337	332,869	2,070	13,246	45,999	454,521	28.24
†892-4394	54,080	460	—	—	4,860	59,400	3.69
†892-4395	5,320	—	—	—	3,000	8,320	.52
955-9632	11,166	—	—	—	—	11,166	.69
956-2950	165	—	—	—	—	165	.01
Total	631,035	596,355	43,205	13,246	325,543	1,609,384	
Percent	39.21	37.05	2.69	.82	20.23	100.00	

[1] See table 1 for descriptions of the pallets.

[2] Coast Guard, Military Assistance Program, GSA, and others.

† Softwood pallets.

* Primary kinds of pallets to be purchased by DGSC in the near future.

Table 12.—*Wooden pallet demand in 1965, by month and Federal Item Identification Number*

(Numbers in boldface indicate knocked-down pallets)

Federal Item Identification Number (FIIN)[1]	January	February	March	April	May	June	July	August	September	October	November	December	Total	Percent
†063-9075*	—	100	5,154	3,050	—	50	—	14	70,518	48,793	124,457	50,000	302,136	18.78
063-9076	—	500	—	—	—	—	—	—	—	—	—	2,500	3,000	.19
†141-7237	200	3,000	400	50	1,000	825	100	500	125	10	40	700	6,950	.43
141-7261*	48,550	5,645	10,737	7,047	13,393	15,269	191,041	31,773	11,240	61,784	48,823	28,594	473,896	29.45
202-2217	608	290	2,600	65	724	2,699	1,692	4,881	877	219	2,925	500	18,080	1.12
222-1044	450	1,009	2,299	1,025	1,676	166	3,250	626	10,472	110	2,991	358	24,432	1.52
222-1046	2,100	1,200	3,700	2,600	1,400	1,754	900	2,916	2,300	3,545	1,900	1,800	26,115	1.62
222-1048	740	—	—	20	—	1,000	—	620	—	1,800	300	—	4,480	.28
222-1051	—	200	—	100	—	100	11,840	1,260	800	14,360	—	—	28,660	1.78
222-1053	165	—	138	20	—	—	200	300	100	—	200	40	1,163	.07
223-6529*	—	20	100	100	500	140	8,400	1,800	40	—	52,400	5,000	68,500	4.26
291-8717*	1,080	480	100	—	120	—	1,620	21,180	1,260	11,640	54,680	1,200	93,360	5.80
542-3294	—	—	—	—	—	—	—	—	—	1	100	100	201	.01
555-0458	172	—	100	1,100	409	5,525	4,488	3,812	3,950	1,000	1,825	2,458	24,839	1.54
599-5326*	5,213	8,985	1,829	16,509	58,088	114,460	37,130	42,675	49,869	17,422	46,680	55,661	454,521	28.24
†**892-4394**	660	620	1,740	2,120	5,400	8,640	14,280	12,580	2,460	3,520	1,380	6,000	59,400	3.69
†**892-4395**	—	—	60	80	320	1,680	760	2,560	800	1,480	120	460	8,320	.52
955-9632	1,706	—	3,000	—	30	—	3	—	—	4,706	—	1,721	11,166	.69
956-2950	—	—	—	—	—	115	—	—	50	—	—	—	165	.01
Total	61,644	22,049	31,957	33,886	83,060	152,423	275,704	127,497	154,861	170,390	338,821	157,092	1,609,384	—
Percent	3.83	1.37	1.99	2.11	5.16	9.47	17.13	7.92	9.62	10.59	21.05	9.76	100.00	—

[1] See table 1 for descriptions of the pallets.

† refers to softwood pallets.

* refers to the primary kinds of pallets to be purchased by DGSC in the near future.

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

The Role of FEES in Campers' Decisions

by Wilbur F. LaPage

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The Role of FEES in Campers' Decisions

THE DECISION that sends a family on a camping trip to a public park or a private recreation area raises all sorts of questions for the resource manager: To build a new campground, or not?; to raise camping fees, or lower them?; to lengthen the camping season, or shorten it?; how to advertise, and where?; and what new services and facilities to provide?

Although it takes thousands of individual family decisions to generate these administrative problems, we often must look to the individual decisions themselves for a means of resolving the problems. For example, what role do camping fees play in decisions of where to camp and how long to stay? How influential is a campground's advertising, accessibility, and reputation? How far in advance is the family camping decision made? What alternatives are considered, and how are they eliminated?

To probe into some of these questions, the Northeastern Forest

Experiment Station, in cooperation with the New Hampshire Division of Parks, made a study of 712 family camping groups to determine how user-fees affect their camping decisions. The study was designed to survey a cross-section sample of campers who visited the New Hampshire state park system between mid-June and Labor Day 1967.[1]

Our sample of 712 camping families (approximately 1 percent of the state park system's 1967 attendance) averaged four camping trips, involving 23 days during the year. Collectively, they camped on 2,900 separate occasions; consequently they made at least that many camping decisions in 1967.

THE DECISIONS

The decision to camp is not a simple, spontaneous, one-step affair. At least three decisions are involved — to camp?, where to camp?, and when to camp? A number of predisposing forces influence all three decisions, such as: (1) the amount and variety of a family's past camping experience; (2) the amount of money invested in camping equipment; (3) preferences for specific campground facilities, locations, and management; (4) awareness of alternatives; and (5) a variety of other factors such as weather, health, and personal finances.

The Main Influences

The more money a family has invested in camping equipment, the less the problem in making the first decision — to camp. This is practically predetermined. So, according to how much our sample of campers has invested for equipment, we should expect to see different patterns of decision-making. For example, large investments seem to lead to longer periods of planning before a camping trip:

Equipment investment (dollars)	*Destination selected over 1 month ago (percent)*
Less than 250	24
250 to 1,000	33
Over 1,000	43

[1] See Appendix for a description of the sampling procedures.

Table 1.—*Differences in factors that influence camping decisions among three categories of past camping experiences.*

Item	Years of experience		
	0 to 1	2 to 4	Over 4
	Percent	*Percent*	*Percent*
Destination of trip decided over 1 month ago*	25	30	37
Campground reputation was most influential in the trip decision***	31	19	12
Have previously visited this campground***	33	51	64
Have invested at least $500 in equipment***	31	45	57
Expenses on this trip exceed $100*	35	40	48

*The differences in these factors among the 3 past camping-experience categories are significant at the 0.10 probability level.

***Significant at the 0.01 level.

Similarly, a family's years of past camping experience will tend to influence not only the decision to camp, but also where and when to camp. These two types of investment — time and money—are inevitably related (table 1). Not only do the more experienced campers tend to have larger investments in equipment: their trip expenses run higher too.

In deciding whether to visit a campground where they have not previously camped, the family tend to evaluate it by one of four methods: (1) by reading descriptions of it in camping directories — 19 percent; (2) by questioning friends who may have camped there — 13 percent; (3) by inspecting the campground in advance — 6 percent; or (4) by using some combination of all three — 58 percent. Almost none of the campers used all the methods we suggested in the interview; and very few wrote to the campground for information, checked with camping clubs, or went to the campground with a contingency plan in mind in case they did not like it.

Decisions of when and where to camp did not follow any single pattern. Most of the decisions for a camping trip were made at least 2 weeks in advance:

Date of decision	*Percent of sample*
Today	12
Yesterday	9
In the past week	23
2 to 4 weeks ago	22
Over 4 weeks ago	32

Despite lengthy planning periods, few campers (27 percent) considered any alternative destinations, and only 5 percent of the campers considered more than one alternative. And because camping is basically a family affair, we were surprised to find that children and family-group decisions played such a small roll in determining when and where to camp:

Who made the decision?	*Percent of sample*
Yourself or spouse	59
Your children	4
Someone else	14
Group decision	6
Don't know	17

Familiarity with the Destination

Because a campground visit at some time in the past is known to influence subsequent trips to the same campground,[2] we decided to examine the camping decisions of campers having different 1967 visit patterns to the New Hampshire park system. Some campers (32 percent) were extremely loyal to the system and camped almost exclusively at New Hampshire parks. Another group (40 percent) camped regularly within the park system, but also did about one-half of their annual camping elsewhere. And a third group (28 percent) used the system on a transient basis, spending only about 15 percent of their 1967 camping time at New Hampshire parks. The loyalty of these three groups toward the park system in 1967 is consistently reflected in their camping patterns during the previous three camping seasons (table 2). And there is a direct relationship between this loyalty

[2] LaPage, Wilbur F. SUCCESSFUL PRIVATE CAMPGROUNDS: A STUDY OF FACTORS THAT INFLUENCE THE LENGTH AND FREQUENCY OF CAMPER VISITS. U. S. Forest Serv. Res. Paper NE-58. 22 pp. NE. Forest Exp. Sta., Upper Darby, Pa. 1967.

and the incidence of a past visit to the campground where the campers were interviewed:

	Campers having been there before (percent)
Transients	28
Regulars	56
Loyalists	67

One of the most striking differences between these three groups is in the trend of their camping participation. From 1964 to 1967, the average number of days camped per year increased by nine days for the transients and by four days for the regulars, but declined by one day for the loyalists (table 3). This more active participation by transients is also reflected in their generally larger investments in camping equipment.

Table 2.—*The percentages of campers who did less than one-third of their annual camping at New Hampshire State parks during 1964, 1965, and 1966, according to three "brand loyalty" classes**

Loyalty class	1964	1965	1966
	Percent	*Percent*	*Percent*
Transients	91	91	85
Regulars	62	57	52
Loyalists	50	51	43

*These percentages are based on the actual number of campers in each loyalty class who camped in each of the given years. There is an annual accretion of between 10 and 16 percent, with the result that out of 704 campers in 1967, only 505 were also campers in 1964.

Table 3.—*The average number[1] of days camped annually by campers who use the New Hampshire state parks system on a transient, regular, and exclusive basis*

Year	Transients	Regulars	Loyalists
	Days	*Days*	*Days*
1964	20	21	18
1965	22	22	17
1966	23	23	17
1967	29	25	17

[1] Corrected to reflect only those campers in the sample who actually camped in each of the years.

Though the loyal campers camp less per year, their individual visits are longer, and are nearly always at a New Hampshire park; and this makes them a very important part of the system's clientele. The average visit lengths for each of the groups were: transients 3 nights, regulars 5 nights, and loyalists 7 nights.

In addition to these differences in camping trend and style, there are a number of significant differences in their decision processes and their travel attitudes. Decisions of when and where to camp were made less than 48 hours in advance by 40 percent of the transients, by 33 percent of the regulars, and by 10 percent of the loyalists. Also, when seeking information about campgrounds they might like to visit, loyalists are much more likely than transients (21 percent versus 7 percent) to seek the advice of other campers. Transients, on the other hand, were about twice as likely to consult guidebooks and directories (35 percent versus 15 percent).

Almost three-fourths of the transient campers would travel over 100 miles for a 2-day camping trip, over 200 miles for 3 to 5 days, and over 500 miles for longer trips. Only about one-third of the loyalists would travel these distances for the same periods of camping.

ATTITUDES TOWARD USER-FEES

Willingness to Pay

Practically without exception, these campers were in favor of paying a fee for the use of public campgrounds. Only seven campers (1 percent) opposed the idea of charging, or were undecided whether they favored a fee or not. Most of these campers defended the fee as a legitimate means of paying the cost of maintaining public camping facilities. Four campers also suggested that fees were a useful method of minimizing crowded campground conditions; and they said that if fees were to be reduced they would probably camp less frequently.

On their current trips, these 712 families spent nearly $15,000 in camping fees, an average of $20 per family (not all at New

Table 4. — *Percent of campers whose camping frequency would not change at fee levels of $1 to $5, by average daily expenditure categories on current trip*

Fee level	Daily expenditure		
	Under $10	About $14	Over $16
	Percent	*Percent*	*Percent*
$1	81	86	92
$2	96	96	94
$3	72	77	79
$4	23	30	35
$5	9	10	16

Hampshire state parks). The amount spent on camping fees represents about one-fifth of their average total-trip expenses ($103). Daily camping expenditures spanned a wide range, but averaged about $11 per family. Campers with high trip costs were more likely to feel that their camping was too expensive, but they were also less likely to reduce their camping frequency if fees were increased (table 4).

Most of these campers felt that a reasonable charge for a campsite (comparable to the one they were camping at) would be in the $2 to $3 range; 65 percent said $3, and 30 percent favored $2. Of the remainder, 3 percent felt that $1 per night was reasonable, while 2 percent were willing to go as high as $6 for daily campsite rentals.

All the campers in this survey were paying at least $1.50 per night at areas without swimming, but not more than $3 per night at campgrounds with swimming facilities. Within this range, we found that approximately 15 percent of the campers were willing to pay more than they had paid for their campsites, and another 15 percent wanted to pay less.

At campgrounds where swimming and boating were available, campers were asked how much they would be willing to pay for their campsites if these attractions were not available. Sixty-five percent said they either would not come at all or would expect to pay less. At campgrounds without these facilities, 32 percent said they would be willing to pay a larger camping fee if swim-

ming and boating were made available (about $1 more). Apparently about two-thirds of the campers at both water-oriented and non-water-oriented campgrounds are attracted to these campgrounds for what they are now, and would not care to see any major change in facilities.

Methods of Payment

The way a camping fee is charged is conceivably just as influential in shaping camping decisions as the amount of the fee. For example, camping fees can be charged on a per person or per-campsite basis; they can be paid in advance or on arrival; and they can be collected manually or mechanically. A majority of the campers (64 percent) wanted the fee to be based on a flat campsite rental charge. Another 29 percent preferred a per-person charge, like that in use by the New Hampshire park system at the time of the survey. And the remaining 7 percent wanted to pay on some other basis — such as an automobile entry fee — or on a graduated scale for the use of special services and facilities.

We presented four alternative methods of payment to each camper. (1) advance payment, on a seasonal-pass basis, for the use of a single campground; (2) a seasonal pass that would be honored throughout all campgrounds of an entire park system; (3) payment by the visit; and (4) payment after the visit through a charge system. No one chose the "camp now — pay later" option. One-fourth favored advance payment, but most of these wanted a system-wide pass rather than a single campground pass.

Because the idea of a system-wide seasonal pass had already been developed for the use of federal outdoor recreation areas,[3] we pursued the method-of-payment question to see what kind of reception the federal pass had received among campers at New Hampshire state parks. Thirty-one percent of the campers had never heard of it, and 60 percent had heard of it but never pur-

[3] The Golden Eagle Passport, authorized by the Land and Water Conservation Fund Act (PL 88-578) of 1965, is not a seasonal camping pass. The annual passport will admit the purchaser, and all who accompany him in a private vehicle, to any federal recreation area at which entrance or admission fees are charged. It does not in most cases cover the cost of use-fees such as for camping facilities in developed campgrounds.

chased one. Nine percent had purchased a pass on at least one occasion, but only two campers had consistently bought one during the 3-year period in which they had been available. Of the 63 purchasers of federal recreation-area entrance permits, 33 felt that their purchase had influenced them to camp more at federal campgrounds than they otherwise would have. All 63 felt that the $7 fee for the annual pass was reasonable; and a few said that it was probably too reasonable and should have been more.

The one out of every four campers who wanted to purchase a seasonal camping pass differed from the others in several obvious but important ways. For example, season-pass advocates were not only much more likely to be on a repeat visit at the time of the interview, but they have consistently spent a higher proportion of their annual camping time at New Hampshire state parks. They also camp more frequently (5 trips versus 3 trips per year), and they spend less money per trip (under $75 on the average). A season-pass is obviously more attractive to those who use the park system regularly than it is to transients.

CAMPING FEES AND CAMPING DEMAND

The Hypothetical Demand Curve

When consumers are presented with an array of decreasing or increasing prices for a commodity, the amount of the commodity they would buy at the several price levels can be graphed to produce a demand curve for the commodity. When a hypothetical range of standardized camping fees is presented to campers, they probably cannot predict accurately the amount of camping they would buy at each fee level. So we simply asked each camper whether he would camp "much more," "much less," or "about as much as he camps now" at standard family camping fees of $1, $2, $3, $4, and $5 per night. Then by assigning an arbitrary but reasonable multiplier to the "much less" and "much more" categories, at each fee level, we could construct a rough demand curve. For example, 1967 camping frequencies could be doubled

for campers who would camp much more, and halved for those who would camp much less at each consecutively higher fee level. This procedure was followed to produce the curve shown in figure 1. The detailed procedure for constructing the curve is explained in the Appendix.

A number of assumptions are built into a curve of this type. The most critical are the reasonableness of the multiplier chosen and the depth of consideration given to answers during the interview. The contribution of the "much more" category to the curve is relatively minor, occurring almost entirely at a fee level of $1, and involving only 1 of every 7 campers (table 5). This is fortunate because there is some doubt about the validity of these responses.

At a later point in the interview, each camper was asked whether he was now camping as much as he would like, and if not why not. The responses of these campers to the latter question appears to be quite inconsistent with their intent to camp more at the $1 fee level. Of these campers, 21 said they were camping as much as they cared to, 56 would like to camp more but do not have the time, only 8 were camping less because of cost, and one actually said he was camping more than he liked to at present.

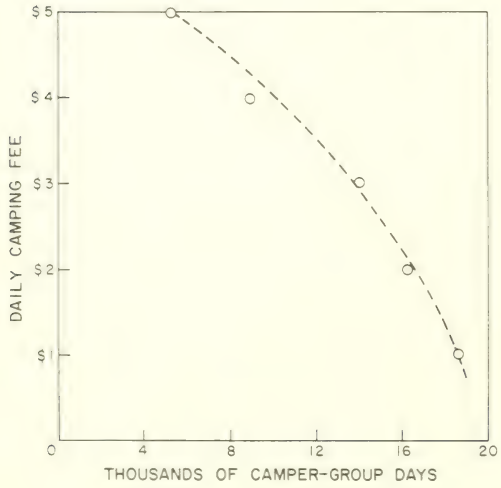

Figure 1.—The demand for camping (as a function of current camping) for our sample of 712 campers at fee levels of $1, $2, $3, $4, and $5 per family night.

Table 5. — *Percent of campers whose camping would be "much less," "much more," or "about the same as now" at standard fee levels of $1 to $5 per night*

Fee per night	Much less	About same	Much more
	Percent	*Percent*	*Percent*
$1	1	84	15
$2	1	96	3
$3	25	74	1
$4	73	27	0
$5	89	11	0

Two groups of campers merit a detailed examination: (1) those whose camping would significantly decline at the $3 level, and (2) those whose camping would remain unchanged at the $4 level. These two groups exemplify the conditions of fee-elasticity and fee-inelasticity, respectively, in their demand for New Hampshire state park camping. That is, a reduction in camping at the level of $3 reflects an immediate responsiveness to fees, or elasticity, while unaffected participation at a $4 level indicates inelasticity.

In terms of annual camping, the "$3 dropouts" are more active campers, so they have a larger volume of camping to bargain with than do the "$4 holdouts." As prices go up, they can afford either to camp less or to do more of their camping elsewhere. Their increased participation takes the form of more trips and shorter trips. Yet for these two groups the averages of days spent camping are not widely different: 27 and 21 days respectively (table 6).

Besides having more flexibility in planning, afforded by more frequent trips, the fee-elastic group is also a younger class of campers. They have fewer established preferences for state park camping, proportionally less experience at New Hampshire state parks, and are more likely to consider alternative destinations. They are also less likely to have experienced higher fees in the past, they are more interested in purchasing a season camping pass, and they are generally more willing to pay extra for a

Table 6. — *Comparison of campers having elastic or inelastic demands for New Hampshire state park camping*

Item	Elastic[1]	Moderately elastic[2]	Inelastic[3]
	Percent	*Percent*	*Percent*
Decision made at least 1 month ago	27	29	42
No alternative destinations considered	67	72	81
Most important consideration was convenience to travel route or to destination	26	29	42
Most important consideration was convenience to home	23	18	13
Generally prefers to camp at state-owned campgrounds	35	44	51
Generally prefers a per-site fee rather than per-person fee	71	66	56
Feels that $2 per day is a fair camping fee	83	69	[4]40
Is willing to pay more for a waterfront campsite	21	16	13
Would like to be able to purchase a season pass	34	25	17
Has experienced fee levels of at least $4 in the past	26	31	40
Went on over four camping trips in 1967	46	37	29
Spent 90 to 100 percent of annual camping at N. H. parks in:			
1964	15	17	[5]29
1965	15	13	31
1966	20	20	31
1967	25	33	38
Would not travel more than 100 miles for 1 to 2 day trip	43	38	31
Would not travel more than 200 miles for 3 to 5 day trip	46	41	38
Would not travel more than 300 miles for longer trip	30	29	34
Current trip is over 8 days in length	38	49	67
Is spending maximum length of time (14) days at this park	10	13	18
Spent over $18 on fees during this trip	30	51	52
Total trip costs exceed the average ($100)	32	39	58
Head of party is under 40 years of age	64	56	43
Number of camping groups in this category	175	341	188
Average number of days camped in 1967	27	23	21

[1] Campers who would camp much less at a standard fee level of $3.

[2] Campers who would camp much less at a standard fee level of $4.

[3] Campers whose participation would remain unchanged at a $4 level.

[4] Only 4 percent of the inelastic group favored a $4 fee.

[5] These percentages are based on the number of campers who actually camped in each of the years.

campsite that has a waterfront. A detailed examination of these two groups is presented in table 6, along with a third, "moderately elastic," group of 341 campers whose camping would begin to decline at the $4 fee level.

The wide differences between the "fee-elastic" and the "fee-inelastic" campers, on over 20 different items (table 6) follow logical patterns of expected behavior and tend to validate the camper's predicted response to the hypothetical fee levels. For example, campers with a fee-elastic demand for state park camping could be expected to have looser decision-making processes and a greater flexibility in their preferences and trip plans. And we were not at all surprised to find that past experience to high camping fees may result in a certain amount of fee conditioning, or lowered resistance, when high fees are next encountered (table 7). Similarly, it is predictable that campers who take relatively few camping trips per year will be less flexible in planning and

Table 7. — *Predicted change in camping activity with changes in daily fees of $1 through $5, by categories of maximum past fee experiences*

Daily fee	Proportion of 1967 camping at maximum exposure of —		
	$1 to $2	$3	$4 to $6
$1	1.15	1.14	1.17
$2	.99	1.02	1.04
$3	.81	.86	.88
$4	.49	.56	.57
$5	.29	.32	.34

Table 8. — *Predicted change in camping activity with changes in daily fees of $1 through $5, by two categories of annual camping participation*

Daily fee	Proportion of 1967 camping by campers who annually take —	
	1 to 3 trips	4 or more trips
$1	1.14	1.17
$2	1.03	1.02
$3	.89	.84
$4	.60	.52
$5	.36	.30

consequently will be less willing to readjust their plans because of relatively minor fee changes (table 8).

The Geography of Fee Attitudes

The use of fee attitudes as a means of studying camping demand has obviously useful aspects. Specifically, the shape the fee curve assumes for different regions and at different types of campgrounds indicates how useful — or useless — fees may be as a management tool. An inelastic demand is unlikely to be responsive to management's changes in fee structures. However, this refers only to the size of fees. Method of charging fees is also a potential management tool, and one that might be useful even in situations of inelasticity.

The demand for state park camping is slightly less elastic in northern New Hampshire than in the southern part of the State (fig. 2), which undoubtedly reflects the northern campgrounds' greater distance from population centers and the consequently lower rate of repeat visits (41 percent in the north versus 70 percent in the south). Incidental to the lower rate of repeat visits is an understandably lower interest in season camping passes in the north (12 percent versus 34 percent).

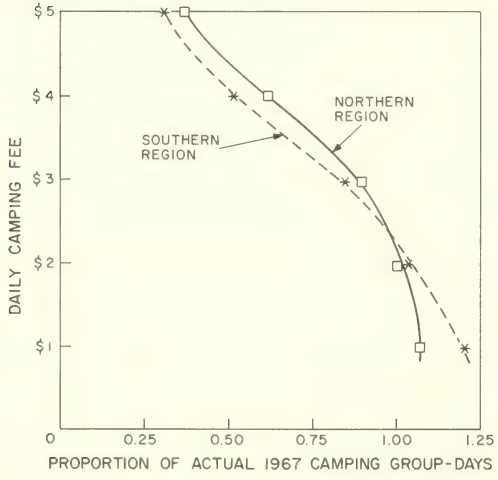

Figure 2. — The demand for state park camping in two regions of New Hampshire, at five daily fee levels, based on the proportion of 1967 camping activity and the camper's predicted response to each of the hypothetical fee levels.

Although campers in the northern part of the State were more reluctant to adjust their camping frequency in response to fees, they were also strongly in favor of a fee system based on a daily campsite rental charge rather than one based on a per-person charge. At the southern parks 57 percent preferred the per-site fee, but at the northern parks 74 percent favored it over the present per-person fee system.

We found some differences in fee-elasticity projections between campgrounds as well as between regions (table 9). The percentage of annual camping that would be influenced by a $3 daily fee ranged from 95 percent to 81 percent at swimming parks, and from 81 percent to 61 percent at parks without swimming. Camping at White Lake State Park apparently would remain almost unchanged between fees of $1 and $3, which bears out its brochure description as "one of the State's most popular campgrounds" (fig. 3).

Table 9. — *Elasticity projections of 1967 camping at five daily fee levels, for each of 11 camping parks and 3 groups of parks in New Hampshire*

Park	Proportion of 1967 camping at daily fees of —				
	$1	$2	$3	$4	$5
Bear Brook (68)[1]	1.22	1.02	0.81	0.48	0.30
Pawtuckaway (58)	1.21	1.04	.85	.52	.29
Greenfield (58)	1.18	1.04	.87	.52	.29
Southern swimming parks:	1.20	1.04	0.85	0.51	0.29
White Lake (68)	1.07	1.02	0.95	0.73	0.43
Lafayette (26)	1.05	1.00	.89	.56	.33
Moose Brook (10)	1.09	1.01	.87	.57	.33
Northern swimming parks:	1.07	1.01	0.91	0.63	0.37
Monadnock (50)	1.05	1.00	0.81	0.62	0.51
Pillsbury (62)	1.46	.96	.80	.45	.28
Crawford (20)	2.00	2.00	.78	.39	.19
Coleman (47)	1.08	1.02	.72	.47	.28
Milan (50)	1.00	1.00	.61	.29	.13
Non-swimming parks:	1.22	1.05	0.77	0.50	0.34

[1] Number in parentheses is the percent of repeat visits in the sample of campers at that state park.

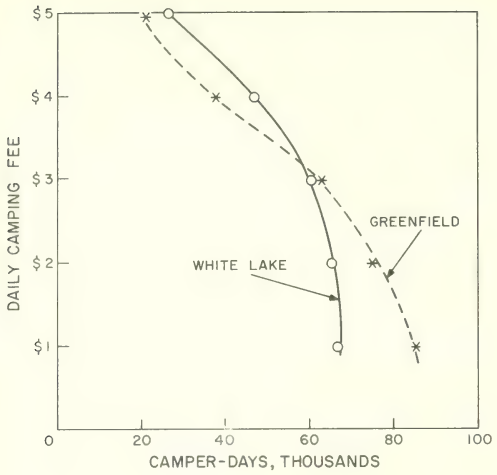

Figure 3—Estimated total attendance at two major New Hampshire parks at five camping-fee levels. Based on 1967 park attendance and visitor response to fee changes.

CONCLUSIONS AND DISCUSSION

It would be a mistake to assume, because fees represent a small portion of the cost of camping, that they are insignificant in the decisions "how much to camp," where to camp, and "when to camp." The evidence in our survey of state park campers shows that both the size of camping fees and the method of payment can influence these decisions. Half of the purchasers of federal recreation-area passports said that their purchase had influenced them to camp more often at federal campgrounds. And about one-fourth of the campers surveyed have a demand for New Hampshire state park camping that could reasonably be termed fee-elastic, because they said they would visit New Hampshire parks much less frequently if they had to pay an average of $3 per day in fees; another 50 percent would do so too at the $4 fee level.

Historically, one of the basic arguments of those who advocate fees and charges for the use of public outdoor recreation resources is their market-like utility. That is, the willingness of people to pay for certain types of recreation gives management a sounder basis for program planning and operation. Although the process of constructing demand curves has limited utility

for the setting of public recreation fees,[4] these curves do contain information for solving problems other than fee setting.

Most obviously, they demonstrate the responsiveness of camping frequency to relatively slight fee adjustments within the $2 to $4 range. This responsiveness suggests a possibility for redistributing demand away from over-popular parks that cannot conveniently absorb all of the demand their popularity creates, and into under-utilized parks of comparable quality and convenience. Such a use of fees would, in fact, be a very logical extension of established practices of charging higher rates at water-oriented campgrounds.

A further extension of this philosophy would be to establish variable charges for different classes of campsites depending upon their desirablity and their development cost. For example, waterfront sites, special facility sites, and extra-large sites all have a good potential for increased earning power. Also, fee adjustment through the use of season passes — as a means of redistributing demand — is worth considering. Relatively slight differences in the cost of a season pass for different campgrounds might conceivably influence the volume of local repetitive use. And system-wide passes might influence campers to visit more parks throughout a park system rather than only one or two near home.

In the demand-curve comparison, the shapes these curves assume for different regions, and for different types of campgrounds, indicate how useful fee manipulation may be as a management tool. For example, a comparison of the fee curves for northern and southern New Hampshire indicates that fee manipulation would be a somewhat more potent tool in the southern part of the State for accomplishing non-revenue oriented objectives.

Obviously, there are some situational limitations to the practicality of fee manipulation for obtaining better distributions of demand. For example, campers in this survey responded to the idea of fee increases without being made explicitly aware of the

[4] Thomas I. Hines has pointed out the legal problems of a public agency setting user-fees with the intention of making a profit in THE PRO AND CON OF CHARGES AND FEES, in Parks and Recreation, 48(2): 102-103, 1965.

Table 10. — *The importance of four selected factors in deciding where to camp*

Item	1 Familiarity with campground	2 Reputation of campground	3 Convenience of location	4 Size of camping fee
	Percent	*Percent*	*Percent*	*Percent*
Ranked as most important for this trip	26	19	51[1]	1
Ranked as most important for an average short camping trip	23	14	55	4
Ranked as most important for an average long camping trip[2]	22	28	40	7

[1] Made up of 3 separate elements of convenience: convenient to home (18%), convenient to travel route (12%), and convenient to a geographic area being visited (21%). These separate components were not collected for the average long and short trips. Convenience to home is undoubtedly a major component of convenience on short trips and a minor one on long trips.

[2] One week or longer.

fact that fee changes would inevitably be accompanied by other changes in the campground as well, such as either more or less crowding. And these other changes might have a more potent effect upon future attendance than the actual fee increase itself. Also, a decrease in fees for the purpose of raising attendance might result in the need for an increase in services — and a resultant increase in management costs. An example might be the desire of management to extend the camping season, or to spread some of the week-end attendance out into the mid-week period. And finally, the convenience of a campground's location and its reputation are much more important in camping decisions than are fees (table 10) at present fee levels.

With the continuing need for more public and private outdoor recreational facilities, it is clear that additional financing of new developments and new services will have to be borne more and more by user-fee revenue. Consequently the size of fees, the basis for the charge, and the method of collection will become more important as tools of the outdoor recreation manager. Their effectiveness as tools will depend in large part upon an understanding of the role fees play in campers' decisions.

■

APPENDIX I

Sampling Method

Because the state parks to be sampled in this study were spread throughout the State, and because they varied in size from the 8 camping units at Milan State Park to the 252 units at Greenfield State Park, the most efficient use of interviewers dictated a cluster sample within parks, and assignment of separate interviewers to the northern and southern parts of the State. Since a separate analysis for interviews taken in each part of the State would fail to reveal whether any differences found would be due to interviewer effects or geographic differences in campers, we followed up the interviews with a postcard evaluation of the interviews.[5]

On a weekly basis, interviewers were given a random list of campsite addresses to visit in their part of the state. Each campsite listed was the center of a cluster of 3 or 4 campsites (4 in the north, 3 in the south), at which heads of camping parties were to be interviewed during that week. In the case of vacant assigned addresses, a random method of substitution was provided. Once the assigned campsite was located and the interview was taken, the interviewer proceeded to the nearest 2 or 3 satellite campsites that were occupied. If a satellite site also happened to be the central site for another cluster, another satellite was chosen in its place. Relatively few conflicts of this type developed because most of the interviewing was done on weekends and on days when campgrounds were relatively full of campers.

The assignment of cluster addresses was made through the use of a random-number generator computer program by first totalling all the available campsites in each region of the State, selecting the random addresses, and then converting these back to specific campsite numbers. The sample was therefore a representative one for each half of the state separately, and for the State as a whole. The sample was not intended to be representative of the 1967 attendance at individual parks, particularly the smaller ones that were sampled very lightly. The resulting sampling fractions for each park and each half of the State are presented in table 11. The fractions are also estimates because reported camper-day attendance had to be reduced by estimated factors of party size and length of visit.

[5] Highly significant differences were found in the campers' reactions to the interviewers; yet there is no evidence that the interviewer differences may have biased camper response. Results of this postal survey are presented in THE CAMPER VIEWS THE INTERVIEW, now being prepared for publication by the Northeastern Forest Experiment Station.

Table 11. — *Number of camping grounds interviewed, and estimated sampling fractions, by separate parks, and by northern and southern park groupings*

State park	Estimated 1967 camping groups	Sample size	Estimated sample
	No.	*No.*	*Percent*
Pawtuckaway	1,233	113	0.92
Bear Brook	1,171	94	.80
Greenfield	2,544	175	.69
Monadnock	330	14	.42
Pillsbury	178	13	.73
All southern	5,456	409	0.75
White Lake	2,267	124	.55
Lafayette	1,316	86	.65
Crawford	193	5	.26
Moose Brook	484	67	1.38
Coleman	149	19	1.28
Milan	48	2	.42
All northern	4,457	303	.68
All parks	9,913	712	0.72

II

Demand Curve Construction

To determine the approximate volume of camping that campers were bargaining with when responding to the series of questions that related predicted participation with increasing fee levels of $1 to $5, we followed these 5 steps:

1. Determine the number of campers whose predicted participation at each fee level would be "much more," "much less," and about "the same as now." This step is presented in percentage form in Table 5.

2. Determine actual 1967 camping participation for all of the campers in each cell of table 5, and check to be sure that the total amount of camping in each participation class equaled the total camping participation for the sample in 1967 (table 12).

Table 12. — *Actual family-days camped in 1967, according to predicted participation levels at daily per campsite fees of $1 through $5*
(In camper-days)

Fee per night	Decreasing participation	Unchanging participation	Increasing participation	Total
$1	122	13,608	2,483	16,213
$2	144	15,896	173	16,213
$3	4,399	11,751	63	16,213
$4	12,197	4,016	0	16,213
$5	14,633	1,580	0	16,213

3. Within table 12, each entry in the "decreasing" column was reduced by the amount of the entry above it, to reflect *net* change at that fee level. For example, at a fee level of $4 there were 12,197 camper-days to be reduced. However, these 12,197 camper-days include 4,399 days that have already been reduced by campers who dropped into the "much less" category at or below the $3 level. Therefore the net change at the $4 level was 12,197 — 4,399, or 7,798 camper-days. These net changes are reflected in table 13.

Table 13. — *1967 camping participation expressed as the net change between increasing daily camping fees*
(In camper-days)

Fee per night	Decreasing participation	Unchanging participation	Increasing participation
$1	122	13,608	2,843
$2	22	15,896	173
$3	4,255	11,751	63
$4	7,798	4,061	0
$5	2,436	1,580	0

4. Within table 13, each entry in the "increasing" column was doubled, since we have decided that "much more" means a doubling in camper-day participation. And each entry in the "decreasing" column was halved, and increased by ½ of the entry immediately above it, ¼ of the entry two lines above it, and so on, reflecting the logic that a camper who would camp much less at x dollars would probably camp much much less at x + 1 dollars. This procedure is summarized in table 14.

5. Finally, each entry in table 14 was summed across the rows to determine the total estimated camping-days at each daily fee level of $1 through $5; and the sums were divided by the actual 1967 camper-day activity (16,213 days) to produce the change ratio at each fee level.

This same procedure was followed in producing each of the separate demand curves presented in this report. It should be noted that this procedure carries an added assumption, over the two presented earlier, that the responses are deliberate and considered, and that the multiplier for "much less" and "much more" are reasonable. The added assumption is explicit in step 4 above, namely that nobody drops out of the camping picture entirely at the range of $1 to $5. They just continually reduce their participation by a factor of 0.5 at each higher fee level.

Table 14. — *Total estimated camping participation at fee levels of $1 to $5*
(In camper-days)

Fee per night	Decreasing participation	Unchanging participation	Increasing participation	Total	Proportion of 1967 camping
$1	61	13,608	4,966	18,635	1.15
$2	41	15,896	346	16,283	1.00
$3	2,149	11,751	126	14,026	.86
$4	4,974	4,016	0	8,990	.55
$5	3,706	1,580	0	5,286	.33

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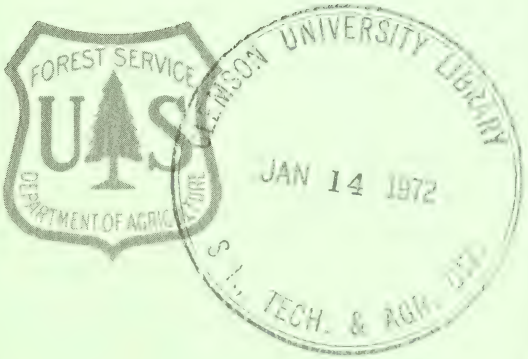
MANGANESE TOXICITY of LEGUMES Seeded in Kentucky Strip-Mine Spoils

by W. A. Berg
and W. G. Vogel



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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

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MANGANESE TOXICITY of LEGUMES Seeded in Kentucky Strip-Mine Spoils

SINCE SPOILS usually lack nitrogen, legumes appear to be a logical choice for quick cover because they are able to convert nitrogen from the air to nitrogen needed for plant growth. However, legumes do not grow well on acid spoils. Many studies of legumes seeded on soils indicate that poor growth under acid conditions often can be attributed to toxicities caused by excess manganese (Mn) and aluminum brought into solution by the acid conditions *(Jackson 1967)*.

The objectives of our study were to investigate whether Mn toxicity occurred on legumes grown on Kentucky strip-mine spoils, whether the amount of toxicity varied among spoils, and whether the toxic effects differed among legume species; and then to find chemical characteristics of the spoil that we can use to predict the occurrence of the toxicity.

Before we could achieve these objectives, we had to know what the Mn toxicity symptoms on the legumes are. Chlorosis on leaf margins was the outstanding Mn toxicity symptom on Korean lespedeza described by Morris *(1948)* and Morris and Pierre *(1949)*. We could not find descriptions of Mn toxicity on the other species used in this study, although a marginal chlorosis was described as a Mn toxicity symptom on red clover by Hewitt *(1946)* and on alfalfa by Ouellette and Dessureaux *(1958)*. Therefore, we produced known Mn toxicity symptoms by growing the legumes in nutrient solutions and then looked for these symptoms on the same species grown in spoils.

METHODS

Three of the species studied, Korean lespedeza (*Lespedeza stipulacea* Maxim.), Kobe lespedeza (*L. striata* (Thunb.) H. & A.), and sericea lespedeza (*L. cuneata* (Dumont) G. Don), are the legumes usually seeded for ground cover on spoils in eastern Kentucky and adjacent areas. We also studied bicolor lespedeza (*L. bicolor* Turcz. 'Natob'), a shrub that has possibilities for wildlife food and cover on spoils; birdsfoot trefoil (*Lotus corniculatus* L. 'Viking'), a species that has grown well on acid spoils in other states *(Struthers 1960)* and in our field studies; and black locust (*Robinia pseudoacacia* L.), which is the tree most commonly planted on spoils in this area.

Nutrient Solution Cultures

Mn toxicity symptoms were produced by germinating and growing the legumes in rafts floating on nutrient solutions. Rafts were made from styrofoam 1 cm. thick, into which 1.5-cm. diameter

holes were punched; glass wool was then inserted into the holes. Seeds were placed on the glass wool and the rafts were floated on nutrient solution in 700-ml. polyethylene containers. The nutrient solution was the Hoagland Number 1 *(Hoagland and Arnon 1950)*; the iron was modified to 0.2 ppm. supplied as sodium ferric diethylenetriamine pentaacetate (Fe DTPA). Treatments were 0.5 ppm. Mn, which is the normal Mn concentration for Hoagland's solution, and 20 ppm. Mn. Solutions were not aerated but were replaced daily. The pH of the nutrient solution was 4.7. This study was conducted in the greenhouse in March and April. There were two replications of each treatment. In a later study the legumes were grown in nutrient solutions containing 0.25, 0.5, 1, 2, 4, 8, and 12 ppm. Mn.

The technique worked well for producing symptoms caused by excess Mn. However, we could not take quantitative data because we encountered difficulties with algae growing in the nutrient solution.

The excess Mn treatments produced a chlorosis on leaf margins of all the species. The contrast between the chlorotic and non-chlorotic areas was pronounced on all species except Kobe lespedeza. For example, the Munsell color notation was 2.5 GY 7/6 on the chlorotic margin and 7.5 GY 5/6 on the unaffected portion of a Korean lespedeza leaflet. On Kobe lespedeza the marginal chlorosis gradually blended into the greener color of the leaflet center.

Small dusky-red spots (10 R 2/2)—a secondary toxicity symptom — appeared in the chlorotic areas on Korean and Kobe; with time the spots turned brown (necrotic). Necrotic spots also developed in the chlorotic areas on the sericea and bicolor lespedeza.

Pot Tests

Samples of 46 spoils from 11 different Kentucky coal strip-mining operations were collected in the fall of 1966. Spoils associated with these coal seams were sampled: Hindman (Hazard 9), Lily, Fireclay (Dean), Harlan, Francis, Mason, Number 11, and Number 12.

Spoils were selected to give a range in pH from neutral to extremely acid. Problems with unoxidized sulfides were minimized by only collecting spoils that had been exposed 6 months or longer. Surface accumulation of salts was avoided by excluding the surface 3 inches of spoil. Spoils were screened and fragments larger than 1.3 cm. diameter were discarded. After it was dried, each spoil was thoroughly mixed, and 1,800 grams was weighed into pots. Since phosphorus is deficient on many spoils, all spoils were fertilized at the rate of 100 ppm. P by adding monobasic calcium phosphate in suspension to each pot and then mixing. Six pots of each spoil were thus treated, and individual pots were seeded to one of the six legumes. The appropriate commercial inoculant was used on all seeds with the exception of locust, which was treated with a small amount of soil from beneath a locust stand. The species treatments were not replicated.

The pots were seeded and placed in the greenhouse on October 3, 1966. The weather in October was generally sunny; there were some cloudy days in November. Artificial lighting was used to give a 12-hour day. Pots were weighed twice a week and distilled water was added to bring them to approximate field capacity; at other times water was added as needed. Notes were taken on the extent of marginal chlorosis on the first leaves that emerged and at weekly intervals thereafter. The degree of chlorosis was rated: slight — up to 10 percent of leaf chlorotic; moderate — 10 to 40 percent of leaf chlorotic; and severe — over 40 percent of leaf chlorotic.

The Korean, Kobe, and black locust grew fast on some spoils and were harvested on all spoils after 40 days growth. The sericea, birdsfoot trefoil, and bicolor grew slower and were harvested after 60 days. When harvested, plants were cut off just above the cotyledons, oven-dried at 70°C. for 24 hours, and then weighed.

After the tops were harvested, the roots were examined, and nodulation was rated as *none, some,* or *good.* Included in the *none* rating were pots where less than half of the plants had one or two very small nodules and the remaining plants had none. Rating nodulation as *good* meant that numerous nodules (varying somewhat among species) occurred on the primary root, and some

nodules occurred throughout the rest of the root system. Nodules in the *good* rating were mostly medium to large as compared to the smaller nodules in the *none* rating. (Nodulation of legumes grown in spoils with pH above 5.5 was used as the standard for judging *good* nodulation.) The intermediate condition of nodulation was rated as *some.*

Spoil pH was determined with a pH meter on a 2 to 1 distilled water-to-spoil mixture that was stirred, allowed to settle 30 minutes, and stirred again before the electrodes were immersed into the supernatant liquid. The pH was determined on spoil samples when the study was begun and later on spoils in which the legumes had grown. No spoil pH varied more than 0.3 pH unit from the initial reading and many were the same before as after cropping. The initial pH values (appendix, table 4) were used when the plant growth data were analyzed.

Water-soluble Mn and calcium were extracted from 20-g. samples of spoils shaken for 30 minutes in 100 ml. of distilled water. After filtration, Mn and calcium were determined by atomic absorption spectroscopy. When determining calcium, all samples and standards were made up to include 1,500 ppm. strontium to prevent interferences. Exchangeable Mn and aluminum were extracted from 20-g. spoil samples by 30 minutes shaking in 100 ml. of 1 N KCl. After filtering, Mn was determined on the extract by atomic absorption spectroscopy; aluminum was determined by the cyanine R method.

RESULTS & DISCUSSION

Chlorosis on leaf margins of legumes grown on the spoils varied from none to severe. The legume species also varied in susceptibility. Korean, sericea, and bicolor lespedeza seedlings developed chlorosis on many more spoils than did Kobe lespedeza, birdsfoot trefoil, or black locust.

When marginal chlorosis occurred it was present on the first leaf or leaflets that emerged after the cotyledons opened. With very severe chlorosis (70 to 100 percent of leaf surface) no further

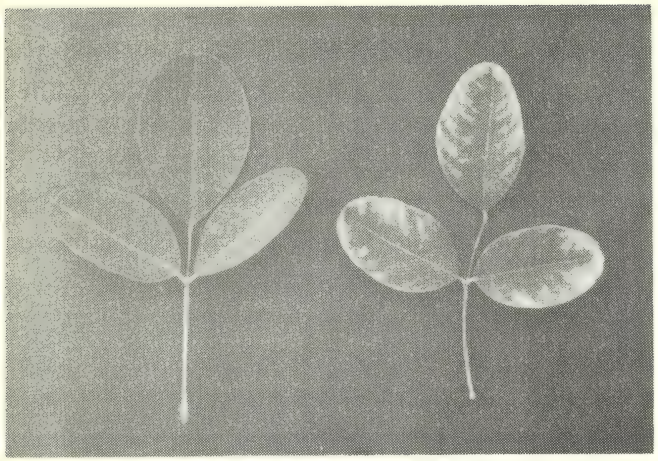

Figure 1. — Bicolor lespedeza leaf on the right shows marginal chlorosis indicating manganese toxicity. Leaf on the left is from an unaffected plant.

Figure 2. — Manganese toxicity symptoms on sericea lespedeza leaflets as shown by chlorosis on leaf margins. None (left), moderate (center), and severe (right).

growth occurred. The chlorotic margins were distinct (figures 1 and 2) on all species except Kobe lespedeza and birdsfoot trefoil. On Kobe the chlorosis gradually became more obvious at the margins. Chlorosis on birdsfoot trefoil was usually on the margins, but it sometimes appeared in irregular spots near the leaf margins.

Small red spots appeared in the chlorotic areas of Korean and Kobe lespedeza leaves and the spots later turned brown. Brown (necrotic) spots also appeared in the chlorotic areas on the sericea, bicolor, and on the more chlorotic birdsfoot trefoil.

These symptoms are the same as those produced in the nutrient solutions where excess Mn was present. The Mn toxicity symptoms on Korean lespedeza as described by Morris and Pierre *(1949)* are also like those symptoms observed in this study. Thus, we assume that Mn toxicity is responsible for the marginal chlorosis and necrotic spotting on the legumes grown on the spoils.

In some spoils, sericea and black locust that initially had light to moderate marginal chlorosis later produced new leaves with no chlorosis. This ability to overcome the toxicity was not noted with the other species.

We have observed the Mn toxicity symptoms on young leaves in field plantings of all the species used in this study.

Yields generally decreased as the degree of chlorosis increased (table 1). A rigorous comparison of the yields with degree of chlorosis cannot be made because aluminum toxicity as well as Mn toxicity undoubtedly inhibits plant growth on many of the acid spoils. Stubby roots with few laterals, a known characteristic of aluminum toxicity, were found on plants grown in some of the spoils; however, incipient aluminum toxicity has no easily recognized symptoms. Differences in plant-available nutrients — particularly nitrogen — among spoils also may have affected yields.

Korean and bicolor lespedeza usually developed symptoms of Mn toxicity when grown on spoils with pH below 5, and occasion-

Table 1. — Relative yields of legumes with given degrees of chlorosis. Observations were included from all spoils from which live plants were harvested

Species	Degree of chlorosis			
	None	Slight	Moderate	Severe
Korean lespedeza	1.0	0.73	0.44	0.15
Kobe lespedeza	1.0	.57	.45	.15
Sericea lespedeza	1.0	.50	.31	.23
Bicolor lespedeza	1.0	.70	.38	.27
Birdsfoot trefoil	1.0	.27	.22	--
Black locust	1.0	.58	.68	.05

Table 2. — Number of spoils in given pH ranges producing manganese toxicity symptoms on legumes

Species	pH range			
	4.0 to 4.4 (11)*	4.5 to 4.9 (12)*	5.0 to 5.4 (11)*	Over 5.4 (4)*
Korean lespedeza	10	8	3	0
Kobe lespedeza	8	2	0	0
Sericea lespedeza	11	8	0	0
Bicolor lespedeza	11	11	4	0
Birdsfoot trefoil	5	1	0	0
Black locust	5	1	0	0

* Basis: Number of spoils in grouping.

ally on spoils with pH in the 5.0 to 5.4 range (table 2). Sericea lespedeza in the seedling stage was also susceptible to Mn toxicity below this pH range, but on some spoils it outgrew the toxicity symptoms. Kobe lespedeza, birdsfoot trefoil, and black locust seldom developed Mn toxicity symptoms on spoils with a pH above 4.4. Thus it appears that spoil pH can be used as a guide for predicting Mn toxicity on legume species seeded in spoils.

Water-soluble Mn in the spoils was not useful in predicting Mn toxicity on the legumes. For example, Korean lespedeza had toxicity symptoms when grown on various spoils containing 1 to 50 ppm. water-soluble Mn, but showed no symptoms when grown on other spoils with as much as 30 ppm. water-soluble Mn. Black locust and birdsfoot trefoil had no toxicity symptoms when grown on the three spoils containing 50 ppm. water-soluble Mn.

Water-soluble Mn in spoils probably does not predict Mn toxicity because high concentrations of soluble calcium and magnesium in some spoils limit Mn uptake by plants *(Hewitt 1946, Ouellette and Dessureaux 1958)*. However, it is not a simple Mn to calcium relationship because the degree of chlorosis could not be related to the ratio of water-soluble calcium to water-soluble Mn.

Nodulation of the legumes also followed definite patterns in relation to spoil acidity. At pH below 4.5, little nodulation occurred on the seedlings (table 3). The pH range 4.5 to 4.9 was a border zone where chances for good nodulation on black locust

Table 3. — Number of spoils in given pH range growing legumes having good nodulation

Species	pH range		
	4.0 - 4.4 (11)*	4.5 - 4.9 (12)*	5.0 - 5.4 (11)*
Korean lespedeza	0	6	10
Kobe lespedeza	1	7	11
Bicolor lespedeza	0	4	10
Sericea lespedeza	0	5	10
Birdsfoot trefoil	1	6	11
Black locust	0	8	10

* Basis: Number of spoils in grouping.

were favorable, and chances for good nodulation on the remainder of the species were fair. At a pH of 5 and above nodulation was usually good on all species. Keep in mind that phosphorus was added to these spoils. Legume growth and nodulation is limited on many spoils by very low amounts of plant-available phosphorus.

Future work on suitability of plants for strip-mine revegetation should include screening not only among but within species for tolerance to toxicities caused by acid conditions. Differences have been found in tolerance to excess Mn among selections of Korean lespedeza *(Morris and Pierre 1949)* and alfalfa *(Ouellette and Dessureaux 1958)*. Foy and his co-workers *(1965, 1967)* are now working intensively on selection of acid-tolerant varieties within agronomically important species.

From this study we conclude that spoil pH is the best guide for predicting Mn toxicity of legumes seeded in spoil. Our results indicate that Korean, sericea, and bicolor lespedeza should be restricted to spoils where pH is above 5.0. However, sericea outgrew the early toxicity symptoms and developed normally on some of the spoils in the 4.5 to 5.0 pH range. The other more Mn-tolerant legumes — Kobe lespedeza, birdsfoot trefoil, and black locust — may be considered for seeding on spoils with pH down to 4.5, although success in stand establishment may be limited by poor or no nodulation on some spoils with pH below 5.0.

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APPENDIX

Table 4. — Chemical characteristics of spoils used in manganese toxicity study

Spoil number	Associated coal seam	pH	Exchangeable —		Water soluble —	
			Aluminum	Manganese	Manganese	Calcium
			ppm.	*ppm.*	*ppm.*	*ppm.*
1	Fireclay	4.5	36	72	11.5	340
2	Fireclay	4.5	54	68	3.3	61
3	Fireclay	3.5	175	115	25.0	525
4	Fireclay	4.0	150	126	23.7	175
5	Fireclay	3.5	300	299	118.0	450
6	Fireclay	3.4	275	80	22.0	420
7	Lily (1)**	3.8	175	23	1.5	3
8	Lily (1)	6.4	2	2	.2	59
9	Lily (1)	5.1	24	29	.2	2
10	Mason	4.1	75	110	16.3	70
11	Mason	4.1	130	58	4.5	26
12	Mason	4.4	200	51	2.3	5
13	Mason	4.2	65	46	8.3	97
14	Mason	5.2	4	14	2.3	61
15	Mason	4.9	26	15	.5	2
16	Francis	4.3	300	66	6.0	23
17	Francis	4.8	90	30	2.3	7
18	No. 11 & 12 (1)	5.1	1	65	23.0	960
19	Hindman (1)	3.6	118	68	26.0	560
20	Hindman (1)	5.4	12	69	3.5	35
21	Hindman (1)	4.2	53	87	26.0	480
22	Hindman (1)	4.7	180	59	.5	2
23	Lily (2)	5.1	13	67	3.0	35
24	Lily (2)	3.8	140	128	16.0	95
25	Lily (2)	4.2	59	171	26.0	160
26	Lily (2)	4.5	33	50	8.0	290
27	Hindman (2)	5.4	60	45	.2	2
28	Hindman (2)	3.9	275	90	8.5	62
29	Hindman (2)	5.3	90	23	.2	2
30	Hindman (2)	4.8	180	46	.2	2
31	Hindman (2)	5.0	26	9	.2	6
32	Hindman (3)	3.8	103	117	52.0	3,000
33	Hindman (3)	6.2	2	17	6.8	2,240
34	Hindman (3)	4.2	71	94	18.1	850
35	Lily (3)	5.4	20	55	.5	8

** Stripping operation number.

CONTINUED

Table 4. — *continued*

Spoil number	Associated coal seam	pH	Exchangeable —		Water soluble —	
			Aluminum	Manganese	Manganese	Calcium
			ppm.	*ppm.*	*ppm.*	*ppm.*
36	Lily (3)	4.9	150	72	.5	3
37	Lily (3)	4.8	22	142	9.8	51
38	Lily (3)	5.3	5	126	2.3	25
39	Hindman (4)	3.0	250	240	175.0	1,840
40	Hindman (4)	7.1	2	2	.5	670
41	Hindman (4)	4.5	75	60	1.8	56
42	Harlan	5.5	27	17	0.0	7
43	Harlan	4.2	200	30	3.5	34
44	Harlan	4.6	42	21	1.0	25
45	No. 11 & 12 (2)	4.9	18	97	53.0	2,800
46	No. 11 & 12 (2)	4.2	125	126	50.0	2,000

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

Rates of value increase for YELLOW BIRCH in New England

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A GUIDE TO FINANCIAL MATURITY

LIKE ANY OTHER businessman, the timber grower needs to know at what rate his investment is earning money for him. He needs to know at what rate his trees are increasing in value, and at what point in their growth they cease to bring him the rate of return he expects. This is the point of financial maturity—the time to harvest the tree.

Foresters have long used biological criteria such as growth rate and vigor to estimate the maturity of a forest tree or stand. In recent years a relatively simple business concept has been made applicable to forest management. Known as the financial maturity concept, this enables foresters to use economic criteria for determining the prospective rate of value increase of a tree.

Using this concept, the Northeastern Forest Experiment Station has begun a series of studies to determine the financial maturity of the important hardwoods of the New England and Middle Atlantic States. The studies include yellow birch, sugar maple, several of the oaks, yellow-poplar, beech, black cherry, red maple, and white ash.

This is a report on the study of yellow birch *(Betula alleghaniensis),* one of the northern hardwoods.

Despite trends toward even-aged management of northern hardwoods in New England, selection of individual trees for cutting is still a common forest-management practice. Selection cutting under uneven-aged management remains in use on areas of aesthetic and recreational importance, or where tolerant species are desired. Commercial thinnings in more-or-less even-aged stands of northern hardwoods are based upon individual tree selection of which trees to remove—and which to retain. And even the final harvest cut in even-aged stands usually is based upon the judgment that a majority of the individual trees in the stand have reached maturity.

Marking practices for northern hardwoods usually are based upon general biological and technological considerations such as life expectancy of the tree, merchantability, current and expected losses from decay and discoloration, and the like. The overall objective is to retain those trees that will produce quality wood and thus produce adequate financial gain. However, to date no guidelines have been available for determining the financial status or financial maturity of individual northern hardwood trees in New England.

This study does provide such a guideline. It gives the timber manager a means of estimating the rate of value increase to be expected of yellow birch trees in the next 10 years.

METHODS

The basic approach was this: we assembled the necessary data to estimate initial stumpage value and future stumpage value—10 years hence—for a range of d.b.h. and height classes, vigor classes, and tree qualities. Then we determined the compound interest rate of value increase over the 10-year period.

Sawlog Quality

The quality data were developed from a sample of 200 yellow birch trees 11.0 inches d.b.h. and larger, located in both mature and immature stands throughout the White Mountain National Forest. These stands had sustained no more than light partial

cutting in the last few years. Tree diameter and number of sawlogs to the nearest half log were recorded. The grade of each 16-foot log (and upper half log) was determined, using U. S. Forest Service standard specifications for hardwood factory-lumber logs.[1]

We decided to express tree value or quality in terms of quality index, defined as the ratio of the dollar value of the lumber in a log or tree to the value of an equal volume of No. 1C lumber. The following price ratios were obtained by summarizing 5 years of quotations (1959, 1961, 1962, 1965, 1966) from the *Boston Commercial Bulletin* and—for products not covered in the *Bulletin*—from a previous analysis of local price structures by Gilbert:[2]

Lumber grade	*Price ratio*
FAS	1.7
Select	1.5
No. 1C	1.0
No. 2C	.5
No. 3C	.4
Construction	.5
Local use	.3

Next, a table of log quality index was developed by multiplying the percent yield of each lumber grade[1] times the appropriate price ratio for various combinations of d.i.b. and log grades (table 1).

Using International 1/4-inch log volumes, we determined the volume of each log in each of the 200 sample trees. The quality index of each log was taken from table 1. The products of quality index times log volume were summed for each tree and divided by tree volume to produce a weighted quality index for the tree.

The sample trees were segregated into three groups based on butt-log grades 1, 2, and 3. A separate multiple regression was

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[1] U. S. Forest Products Laboratory. HARDWOOD LOG GRADES FOR STANDARD LUMBER. U. S. Forest Prod. Lab. Rpt. D1737, 66 pp., illus., 1953. Hardwood log grades are more recently described in: Ostrander, M.D., A GUIDE TO HARDWOOD LOG GRADING, U. S. Forest Serv. NE. Forest Exp. Sta., 50 pp., illus., 1965.

[2] Gilbert, Adrian M. SAMPLING THE QUALITY OF HARDWOOD TREES. U. S. Forest Serv. NE. Forest Expt. Sta., Sta. Paper 114, 18 pp., illus., 1959.

Table 1.—*Quality index of yellow birch for 16-foot logs, by d.i.b. and log grade*

Di.b. (inches)	Log grade				
	1	2	3	4	5
8	—	—	0.58	0.5	0.3
9	—	—	.51	.5	.3
10	—	0.65	.53	.5	.3
11	—	.70	.48	.5	.3
12	—	.75	.47	.5	.3
13	0.94	.71	.49	.5	.3
14	1.02	.78	.51	.5	.3
15	1.03	.74	.50	.5	.3
16	1.03	.79	.55	.5	.3
17	1.11	.68	.46	.5	.3
18	1.18	.81	.44	.5	.3
19	1.26	.94	—	—	—
20	1.18	.75	—	—	—
21	1.24	1.03	—	—	—
22	1.38	.98	—	—	—
23	1.28	.89	—	—	—
24	1.40	—	—	—	—

computed for each butt-log grade, relating weighted quality index to tree d.b.h. and log height:

Butt grade 1:

$$QI = .641099 + .016125\ (\text{d.b.h.}) - .060146\ (\#\ \text{logs})$$

Butt grade 2:

$$QI = .585487 + .00839\ (\text{d.b.h.}) - .04112\ (\#\ \text{logs})$$

Butt grade 3:

$$QI = .443344 - .004868\ (\text{d.b.h.}) - .009835\ (\#\ \text{logs})$$

Veneer Quality

In both value and volume, veneer is an important usage of yellow birch. To reflect veneer quality, we took six log grades used by a large veneer industry in New Hampshire:

Grade	*Min. d.i.b. (inches)*	*Allowable defects*
AA	16	None.
Aircraft	14	No surface defect; 3-inch end defect well centered.
Select	12	1 defect.
No. 1	12	2 defects.
No. 2	12	4 defects.
No. 3	10	None; no sweep allowed.

These veneer specifications apply to logs approximately 8½ feet long. Additional specifications, which we need not mention here, are given on sweep, seams, and ring shake. As described later, these veneer specifications were used to describe a range of hypothetical veneer-log trees for purposes of computing value increases and compound interest rates.

Vigor Class

Growth data for yellow birch are not sufficiently accurate to define the relationships between descriptive vigor classes (based on crown class, etc.) and d.b.h. growth. For purposes of this study, it was necessary to establish four arbitrary vigor classes based on 10-year diameter growth:

Vigor class	*10-year d.b.h. growth (inches)*
1	2.0
2	1.5
3	1.0
4	.5

These vigor groups cover fairly well the possible range in 10-year diameter growth. Vigor 1, for example, represents an unusually fast-growing yellow birch under New England conditions.

Value Increase

Value increase computations were run for hypothetical sawlog trees defined by all likely combinations of vigor class (four classes), U. S. Forest Service butt grade (three classes), initial d.b.h. (ten 2-inch classes), log height 10 years hence (three classes—same, increase of .5 log, increase of 1 log), and butt grade 10 years hence (same, increase of 1 grade).

Similar computations were run for a series of hypothetical veneer-log trees defined by combinations of vigor class (four classes), veneer butt grade (six classes), three log heights (1.0, 1.5, and 2.0), six veneer upper-log grades, and eight 2-inch d.b.h. classes.

For sawlog trees, initial stumpage value was computed by starting with a value of $200.00/M for No. 1C lumber on the

Boston market. This value was reduced by 5 percent for brokerage and 12 percent for profit and risk. We then multiplied by tree quality index, as estimated by the regression equations previously given. Then the following conversion costs, based on locally used appraisal figures, were subtracted:

	Cost per thousand
Woods costs	$22.00
Transportation	13.25
Logging overhead	2.50
Erosion control	.25
Temporary roads	2.79
Miscellaneous development costs	2.79
Manufacturing costs	38.00
Total	$81.58

The result was multiplied by tree volume in M board feet to give initial stumpage value.

Initial stumpage value per M board feet for veneer trees was computed by beginning with appropriate log prices at the mill, reduced by a 12 percent profit-and-risk margin:

Veneer log grade	*Advertised*	*Reduced 12%*
AA	$300	$264.00
Aircraft	260	228.80
Select	210	184.80
No. 1	160	140.60
No. 2	120	105.60
No. 3	120	105.60

For each category of veneer-log tree, mill price of each log in the tree was multiplied by log volume, and the results were summed for the tree. Harvesting and transportation costs (without erosion-control charges) equal to $43.33 were multiplied by tree volume and subtracted to provide an estimate of initial stumpage.

Future stumpage value—10 years hence—for both sawlog and veneer trees was computed in the same way as initial stumpage value, but using assumed vigor class to provide an estimate of future d.b.h. and incorporating any options on change in merchantable height or butt-log grade.

Finally we determined the compound interest rate that represented the change from initial to future stumpage value for each class of tree.

RESULTS

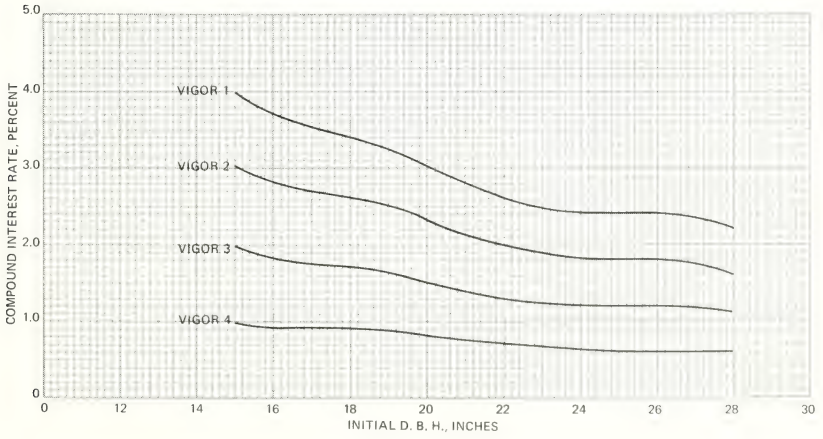
Value Growth Rate

First we will examine the rate of value increase due to diameter growth alone. In the next sections we will examine the effects of changes in grade and merchantable height.

Compound interest growth rates were plotted over d.b.h. for 2-log sawlog trees with grade-1 butts (fig. 1). The curves were fitted by eye through actual plotted points. Curves for grade-2 butts and 1-log trees were similar in shape and amplitude; thus similar general conclusions apply to all.

A compound interest rate of 3 percent or better was exhibited by vigor-1 trees smaller than 20 inches d.b.h. and by vigor-2 trees smaller than about 17 inches d.b.h. Vigor-3 trees never exhibited compound interest much better than 2 percent. Rates for vigor-4 trees seldom exceeded 1 percent.

Figure 1. — Compound interest rates over d.b.h. for sawlog trees in vigor classes 1 to 4 with 2 logs and grade-1 butts.



Trees with grade-3 butt logs exhibited negative stumpage valaues. Thus compound interest rates were meaningless for trees in this class.

Compound interest rates for veneer-log trees generally were lower than for sawlog trees, probably because of the high value of the former. The range in interest rates by vigor classes for trees with log grades ranging from select to AA were:

Vigor class	*Percent*
1	1.6-2.8
2	1.3-2.1
3	.8-1.5
4	.4- .8

There was a tendency for smaller trees with lower grade to exhibit the higher interest rates.

Merchantable Height Change

Yellow birch trees in the 12-, 14-, and 16-inch classes, especially vigor-1 and -2 trees, may increase in merchantable height by 0.5 log over a period of 10 years. Yellow birch trees larger than 16 inches usually have reached their peak of merchantable height development.

An increase in merchantable height over a 10-year period had a consistent effect upon compound interest rates of value increase. For example, a 16-inch, 2-log, vigor-3 sawlog tree with butt grade 1 produced a 1.8-percent compound interest value increase over a 10-year period when merchantable height remained the same, but a 2.6-percent rate when merchantable height increased to 2.5 logs. A comparable vigor-2 tree produced a 2.8-percent increase with no change in merchantable height, and 3.5 percent when merchantable height increased to 2.5 logs. Increases in compound interest rates attributable to changes in merchantable height tended to be a little larger than those mentioned above for 12- and 14-inch trees (which commonly increase from 1.5 to 2 logs).

Grade Changes

Changes in log grade over a 10-year period have an important influence upon compound interest rates of yellow birch. For

vigor-3, 2-log sawlog trees, an increase in butt grade from grade 2 to 1 produced an interest rate of over 8 percent (table 2). The comparable rate for similar trees that did not increase in butt grade was between 1 and 2 percent.

Vigor-3, 2-log veneer trees exhibited interest rates between 2.1 and 3.7 percent when the butt grade increased by one grade (table 2). The comparable rate for trees with no grade increase was 1 to 1½ percent. Slightly higher interest rates than those in table 1 were shown by vigor 1 and 2 trees.

Table 2.—*Compound interest rates for sawlog and veneer-log trees increasing by one butt-log grade over a 10-year period —for 2-log, vigor-3 trees*

D.b.h. (inches)	Veneer-log trees[1]			Sawlog trees		
	Initial butt grade	Final butt grade	Interest rate (percent)	Initial butt grade	Final butt grade	Interest rate (percent)
16	Select	Aircraft	3.7	2	1	8.8
	Aircraft	AA	3.1			
18	Select	Aircraft	3.1	2	1	8.7
	Aircraft	AA	2.4			
20	Select	Aircraft	3.1	2	1	8.5
	Aircraft	AA	2.5			
22	Select	Aircraft	2.8	2	1	8.3
	Aircraft	AA	2.1			
24	Select	Aircraft	3.0	2	1	8.1
	Aircraft	AA	2.4			

[1] All veneer-log trees assumed to have a select top log.

The effects of grade change can be generalized by saying that an improvement in butt grade of sawlog trees from grade 2 to grade 1 produces at least a 2- to 4-fold increase in interest rates over the unaugmented rate; while a butt-grade change in veneer-log trees results in roughly double the normal rate.

The effects of a change from a sawlog grade to a veneer grade are difficult to evaluate precisely because (1) veneer logs and sawlogs are not graded on the same basis, and (2) we used a different appraisal system for the two types of logs. However, on the basis of size alone, it is possible and likely that a small

grade-1 log could move over a 10-year period into the aircraft or AA classes. If a 16-inch, 1-log, grade-1, vigor-1 tree moved into the aircraft grade, our data indicate that the compound interest rate would be about 16 percent. A change to AA grade would produce a rate of about 18 percent.

DISCUSSION & RECOMMENDATIONS

Results of this study indicate that compound interest rates earned by yellow birch trees are greatest—up to 8 percent—where the butt log increases in grade. Large trees that do not increase in grade usually have low interest rates, although small fast-growing trees may earn rates of 3 or 4 percent—even without an increase in grade. Interest rates may also be augmented a little by increases in merchantable height.

Trees left as growing stock or crop trees after a harvesting or thinning operation should be those that show the best promise for future grade improvement. Trees that have reached their peak of grade improvement generally will not produce high or even reasonable rates of return.

In trees with a minimum amount of grade defect, size is a major determinant of log grade. Thus tree and log size set an upper limit on grade potential. A butt-log must be 13 inches d.i.b. at the small end to qualify as a grade-1 sawlog and about 16 inches d.i.b. for a top-grade veneer log. Thus a 20-inch, 1-log tree probably has reached, or passed, the peak of grade improvement. Upper logs must be 16 inches d.i.b. to qualify as top-grade veneer logs or sawlogs. Thus a 22-inch, 2-log tree would have reached, or passed, the peak of grade improvement. Of course in marking individual trees, the characteristics of each given tree—particularly the nature and extent of external and internal defect—should be considered in arriving at a judgment on the possibilities of future grade improvement.

Results of this study provide the basis for some recommenda-

tions on long-range tree harvest size objectives. Individual trees in a selection forest or the main body of an even-aged stand of yellow birch cannot be grown beyond 22 inches d.b.h. without sacrificing individual-tree rate of value increase. Where surface defect rules out the possibility for top-grade sawlogs or veneer logs, a size objective of about 18 inches d.b.h. (12 inches d.i.b. at the top of the second log) seems like a reasonable goal.

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

THE UNIT-LOAD EXPLOSION in the FOOD INDUSTRY

A study showing the relative importance of several materials-handling systems in shipping food products

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by John J. Strobel
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THE UNIT-LOAD
EXPLOSION in the
FOOD INDUSTRY

A study showing the relative importance of several materials-handling systems in shipping food products

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THE WOODEN PALLET—born in World War II out of the need for moving and storing vast volumes of materials—offers exciting opportunities today not only for the food industry and other user industries, but also for the forest industries. This was revealed by a recent cooperative study of the food industry by the U. S. Forest Service and Better Management Services, Inc.

For the food industry, a unit-load system using wooden pallets, coupled with an efficient pallet-exchange system, offers opportunities for increased efficiency and cost savings in handling the great volumes of products that move daily from manufacturers to distribution centers to retail stores.

For the forest industry, this offers promise of greatly expanded markets for the low-grade timber resource, which can abundantly produce short pieces of good wood that are ideally suited for making pallets. Expanded use of pallets in a national pallet-exchange program by the food industry alone would provide profitable use for a volume of low-grade timber equal to the total volume of hardwood timber cut for all uses in the United States today.

This study, initiated by the Northeastern Forest Experiment

Station's Forest Products Marketing Laboratory at Princeton, West Virginia, is the first of a series of studies designed to evaluate the performance of wooden pallets and develop criteria for operating a national pallet-exchange program. This study was concerned with the systems used in the food industry for handling shipments.

Background

Not too many years ago finished goods were moved with the two-wheel hand truck and then "stair-stepped" to a ceiling height of 10 to 14 feet. Orders were selected onto 4-wheel flat trucks or 2-wheel hand trucks and moved to the shipping area where the product was loaded piece by piece into the carrier's equipment, and was secured for transit with lumber dunnage. Handsaws, nails, and hammers were the tools for moving products between shipper and receiver. At intermediate warehouses, again the goods were handled piece by piece — loading, unloading, storing, selecting, and shipping to the retail outlet where the consumer could see and purchase the goods. It mattered not, in the distribution cycle from manufacturer to consumer, whether the order was for a few cases or several thousand cases — the handling was the same.

The constant search for more efficient and economical ways to handle products led manufacturers and intermediate distributors to begin using wooden pallets and forklift trucks to move and store multiples of a product as single units. The unit-load concept came into its own within the warehouse. After World War II, traffic men realized that if the benefits of unit-load handling within the warehouse could be extended throughout the shipping and receiving cycles, distribution costs could be reduced substantially. In the late 1940's the building-materials industry, oil refineries, the chemical industry, breweries, meat packers, and steel fabricators began shipping their products on wooden pallets. Many companies used expendable pallets; others successfully began pallet-exchange programs.

In 1960 the food industry became a prime prospect for this method of unit-load handling. The problems that resulted from

multiple manual handlings as well as variety in warehouse layouts and operating systems, prompted traffic men to search for a better way to handle products. They concluded that the concept of the unit load, applied in a total concept approach, would produce significant cost reductions badly needed in an industry that operated on a 1-percent profit margin. The successful, though limited, use of this concept in other industries and in Europe provided useful guidelines for the food industry.

Trade associations studied the European pallet-exchange programs. Sweden had initiated such a project in 1947, and by 1960 about 1,000 companies were participating. Thirteen other nations in Western Europe now have exchange programs, and an international pallet-exchange program is operating among Austria, Switzerland, and Western Germany.

In 1962 a major U. S. food manufacturer took a step forward by initiating a pallet-exchange program among 11 of its processing plants and 20 of its sales and distribution center warehouses and more than 600 customers' warehouses. Thirty-one rail carriers invested $19 million in special car equipment for this one company alone. The carriers expected increased revenue per car as a return on their investment due to faster turn-around, reduced claims for loss and damage, and reduced car maintenance because of clean loads and special devices to secure them. A central traffic group was given responsibility for scheduling these cars, and personnel at the food-distribution centers were supposed to expedite loading or unloading and insure release of the car within 48 hours after effective placement at the dock. Following this lead, many other companies began to plan handling programs based on the wooden pallet and the conventional forklift truck.

A second system of handling unit loads was introduced in 1962 when another food manufacturer developed a system of handling loads on fiber slip sheets with special attachments for a forklift truck. This system is commonly referred to in the industry as "push pak."

In 1964 a third food manufacturer introduced another system of handling loads on slip sheets. Known as "pull-pak," this sys-

tem requires a gripper bar on the special forklift attachment developed from the "push-pak" system.

In 1964 and 1965 another manufacturer serving the food industry introduced the clamp-truck system they had been using internally for 9 years, which employed special clamp attachments on a forklift truck.

By January 1966, 39 companies were participating in wooden pallet-exchange programs; 11 companies were using push-pak and/or pull-pak; and several companies continued to experiment with the clamp-truck system.

PROFILE OF THE FOOD INDUSTRY

The food industry is national in scope. Over 500 major manufacturers move their products to over 2,000 chain and wholesale food distribution centers, who in turn ship to 325,000 retail stores. Some 15 billion cases of products are handled annually.

Millions of shipments are involved in the movement of goods. One large distribution center alone will receive 3,000 carloads and 12,000 truckloads a year via common carrier, plus many more thousands of shipments via its private carrier operation.

The industry uses specially designed rail cars for unit-load systems. These cars cost $20,000 compared to the cost of $8,000 for a standard box car. These special cars are commonly assigned for the exclusive use of individual firms. They travel empty for 50 percent of their mileage.

The food industry has been exposed to every conceivable problem inherent in unit-load handling, with its 7,000 unlike items in every type of package or shipping container designed. The industry has professionalized the role of its traffic managers by extending their responsibilities into warehousing, inventory control, order-selecting systems, and many other company interrelated activities.

This industry occupies a central position in the development of unit-load handling. One of the largest industries in the United States, it overlaps many other industries. During the last 5 years the food industry has devoted more effort than any other industry to designing, testing, and installing systems of unit-load handling.

PROFILE OF THE FOOD-DISTRIBUTION CENTER

Because the food-distribution center is responsible for moving products to the retail stores and for maintaining stock levels sufficient to meet their requirements, it necessarily controls the chain of events in product movement from the manufacturers. The product, production schedules, and storage requirements are dictated to a large extent by the quantities and the line-items mix ordered by the distributor. The manufacturer in turn specifies the transportation equipment that the carrier must provide.

The typical warehouse is a modern one-story building not more than 10 years old. Inside it has 20 feet of clear stacking height, which is consistently utilized. The rail receiving dock is either covered or totally enclosed within the building; and more often than not it has a double track that can be bridged through one car to unload the other.

The distribution center normally stocks 5,000 to 7,000 items of dry grocery products. Small slow-moving items that are stocked in less than one pallet load are stored on gravity-flow racks to obtain more facings for the order-selecting operation. If the maximum inventory of an item is two or three pallet loads, the pallets are usually placed on the order-selecting line in either portable or permanent racks. If the maximum inventory of an item exceeds three pallet loads, the excess is usually placed in a designated reserve area. Because space is scarce, it is carefully controlled, and areas are assigned for specific products.

Too often products are stored in the staging areas at both rail and truck docks. This causes congestion and loss of efficiency in loading and unloading.

Food-distribution centers use many different kinds of equipment. In this study, we found that 41 unlike pieces of equipment were used to handle wooden pallets of like size.

The equipment most commonly used includes electric or propane powered straddle-type and counterbalanced forklift trucks, transveyors, electric worksavers, and walking forks. Much of the receiving equipment is in the 5,000-pound class so that two pallet loads of the heavier products can be moved as one load.

Most forklift trucks are designed to handle both conventional and multi-tine attachments to permit handling loads unitized on either pallets or slip sheets. Usually the distribution center has a preference for certain kinds of handling equipment, developed from experience with daily operating problems.

The specially equipped rail cars received at the food-distribution center are often held for 4 to 7 days in the yard, and are handled in the same manner as the standard box cars. This results in inefficient use of these cars, which are designed for rapid loading and unloading. They should be grouped and handled separately so that they can be pulled and returned to service with minimum delay. Delays are most often caused by shortage of manpower, congestion in the dock areas, and poor scheduling.

SCOPE

In this study, begun in 1965, detailed information was collected on 2,706 shipments moving from 422 manufacturers by rail and truck carriers to 10 major distribution centers. The shipments consisted of:

Item	*Rail*		*Truck*	
	No.	*Percent*	*No.*	*Percent*
Shipments	709	26.0	1,997	74.0
Pieces	1,127,818	35.0	2,032,048	65.0
Pounds	34,652,535	37.9	56,998,344	62.1
Man-hours	4,402	40.5	6,443	59.5

METHODS

The products were classified on the basis of their physical handling characteristics into five product groups:

Group I—paper products.—Bags, meat trays, napkins, toilet tissue, towels, facial tissue.

Group II—low-density items.—Baking soda, cereals, charcoal, crackers, cookies, dried fruit, pet food in bags, toys, games.

Group III — canned goods — Evaporated milk, fish, fruits, juices, pet food, pork and beans, soups, spaghetti, vegetables.

Group IV—products in glass.—Baby food, catsup, jams, jellies, spreads, salad dressing, shortenings, oils, syrups.

Group V — heavy packaged goods. — Baking mixes, flour, powdered milk, rice, salt, soaps and detergents, sugar.

Each shipment was classified by method of unit-loading as defined below:

Floor-loaded (FL).—Cases are loaded in the car or truck piece by piece.

Wooden pallet/floor loaded (WP/FL). — A portion of the shipment is loaded in units on wooden pallets; the remainder of the order is dead-piled in the doorway, or as dunnage alongside the unitized portion, or on top of the unitized portion; or a combination of these methods.

Slip-sheet/floor-loaded (SS/FL).—A portion of the shipment is loaded in units on slip sheets (push-pak or pull-pak); the remainder of the order is dead-piled in the doorway, or as dunnage alongside the unitized portion, or on top of the unitized portion; or a combination of these methods.

Clamp-truck/floor-loaded (CT/FL).—A portion of the shipment is loaded in unit blocks with a clamp truck; the remainder of the order is dead-piled in the doorway, or as dunnage alongside the unitized portion, or on top of the unitized portion; or a combination of these methods.

Wooden pallets (WP).—The entire shipment is unit-loaded on wooden pallets, either single- or double-decked.

Slip sheets (SS).—The entire shipment is unit-loaded on slip sheets (push-pak and pull-pak), either single- or double-decked.

Clamp truck (CT).—The entire shipment is loaded in blocks with clamp-truck equipment.

Information and data were collected at the 10 major food-distribution centers by tallying all incoming shipments for a period of 1 week at a time. A total of 54 weeks of shipments were tallied—a minimum of 3 weeks and a maximum of 6 weeks shipments at each distribution center. Items of information tallied on each shipment included: shipper, carrier, and receiver identification; carrier equipment number, dimensions and nomenclature; purchase-order number; terms of purchase; number of line items, number of pieces, weight, and number of unit loads in each shipment; dates ordered, shipped, scheduled to arrive,

actual arrival, placed at receiving dock, unloaded, and release of equipment; time and man-hours required to unload; and data on overs, shorts, and damages.

The following productivity measures were computed from the basic data for each shipment:

Man-hours. — The number of men used for unloading times the number of hours required. For rail shipments, *start time* began with the start of the workers' assignment to unloading (normally this coincided with the start of the workday). Working time included coffee breaks, setting dock plates, removing dunnage, tallying and marking items, and all other paid time spent by the employees assigned to the car, but did not include lunch periods and those times when employees were assigned to tasks other than unloading the car. *End time* was recorded when the last item was removed from the car and tallied by the employee assigned to the car, and the pallets or dunnage were returned and the car door was closed.

For truck shipments, *start-time* began when the driver shut off the truck motor after having backed into the receiving dock. Working time included coffee breaks, lunch periods, waiting for pallets, for equipment, for receiver's employees, for space on the dock, and all the time when the truck was in the bay before the last item of the shipment was removed.

Tons per man-hour.—Computed as the quotient of the weight of the shipment in tons, divided by the number of man-hours required to unload.

Cases per man-hour.—Computed as the quotient of the total number of cases in the shipment, divided by the number of man-hours required to unload.

Cost of labor.—Direct labor cost for unloading was computed for each shipment. Two adjustments were made so that a comparison could be made when evaluating direct labor receiving costs. At several of the distribution centers, supervisory wages were charged to general administrative expense; and at other centers they were charged to operating expense. In this study, all supervisory wages were charged as direct operating expense for unloading.

Because of differences in geographical location, hourly wage rates ranged from $2.87 to $3.27. An average wage of $3.00 per hour was used in all computations to obtain comparable labor costs per car, per ton, and per case.

Individual companies may also want to consider the wage differentials between forklift operators and warehousemen who unload floor-loaded cars; and between day shifts and night shifts where costs of either unit-load or floor-loaded shipments will be slightly higher. However, these differentials probably are so small relative to the savings obtained from unit-load handling that they may be ignored for all practical purposes.

GENERAL

Motor carrier deliveries accounted for 74 percent of the shipments, 65 percent of the pieces, and 62 percent of the weight. Rail carriers accounted for the rest.

In 1964, 31 percent of the rail shipments were unitized; and in 1965, 38 percent were unitized (fig. 1 and tables 1 and 2). Most of this increase was in fully unitized shipments on wooden pallets.

Rail shipments — whether floor-loaded or unitized — are unloaded entirely by distribution-center personnel. Motor-carrier shipments, when floor-loaded, are unloaded by carrier personnel; unitized shipments may be unloaded by either distribution-center or carrier personnel.

At the close of 1964, about one-fourth of the motor carriers were experimenting with unit-load handling, and about 5 percent of the product movement was unitized on wooden pallets. By the end of 1965, motor carriers were moving 45 percent of their volume in unitized loads; and 93 percent of the unit loads were on wooden pallets.

Motor carriers were able to adopt unitized handling systems relatively fast because 85 percent of their present equipment is adaptable to the 48-inch by 40-inch pallet size.

Tests showed that it is more efficient for distribution-center employees to unload fully unitized shipments from motor car-

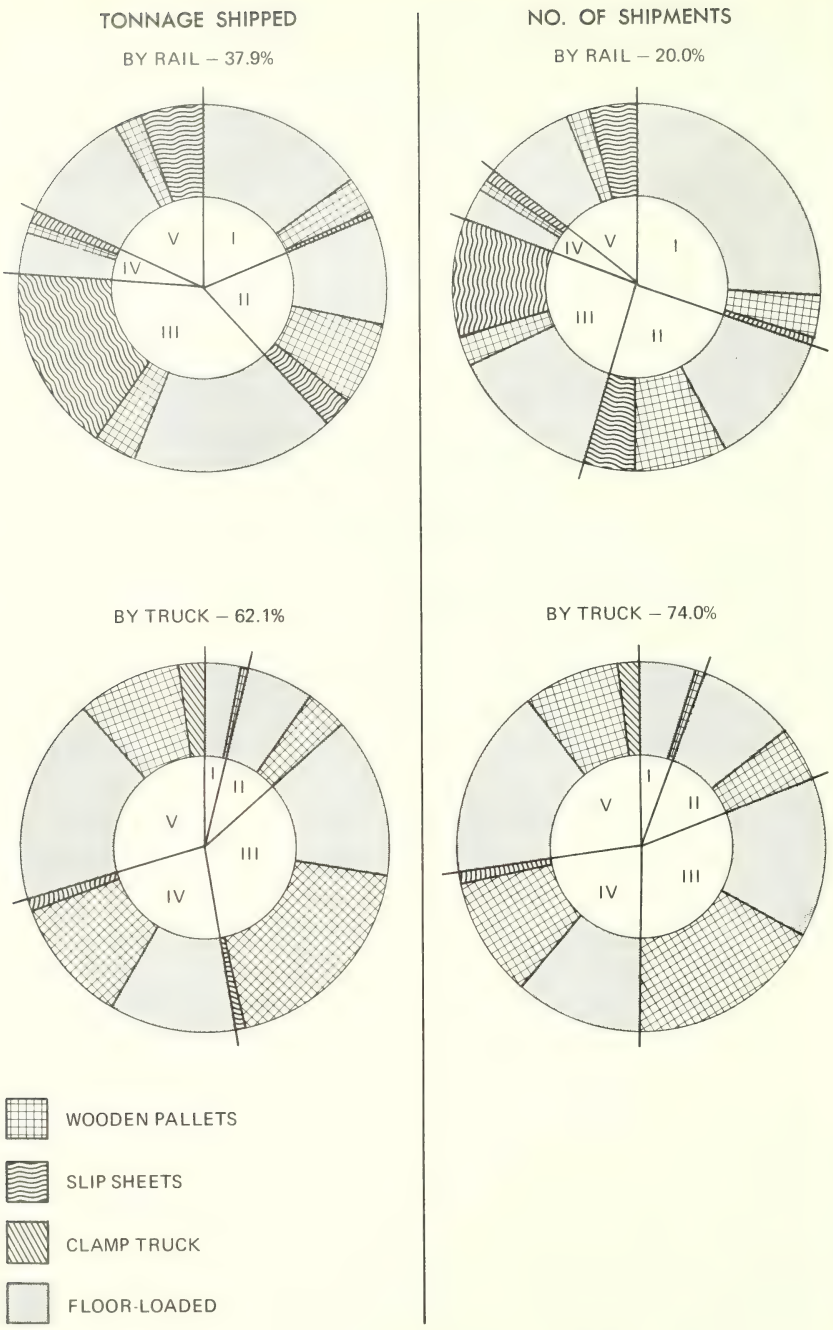

Figure 1.—The pattern of product-handling methods for different product groups and shipping methods.

Table 1.—*Summary of rail and truck shipments for the five product groups*

Product group	Item	Rail		Truck	
		No.	*Percent*	*No.*	*Percent*
I	Shipments	214	30.2	118	5.9
	Pieces	161,115	14.3	58,844	2.8
	Weight in pounds	6,471,307	18.6	2,051,396	3.5
	Man-hours of labor	1,215	27.6	379	5.8
II	Shipments	173	24.4	267	13.2
	Pieces	325,557	28.9	299,578	14.7
	Weight in pounds	6,792,242	19.6	5,043,375	9.4
	Man-hours of labor	1,154	26.3	862	13.3
III	Shipments	185	26.0	622	31.3
	Pieces	383,742	34.0	612,052	30.2
	Weights in pounds	13,166,632	37.9	19,565,490	34.4
	Man-hours of labor	1,110	25.2	1,663	25.8
IV	Shipments	33	4.7	451	22.5
	Pieces	72,555	6.4	562,928	27.8
	Weight in pounds	1,950,246	5.6	13,309,684	23.4
	Man-hours of labor	219	5.0	1,490	23.2
V	Shipments	104	14.7	532	27.0
	Pieces	184,849	16.4	498,646	24.5
	Weights in pounds	6,272,108	18.3	16,668,399	29.3
	Man-hours of labor	704	15.9	2,049	31.9

riers. Distribution-center personnel required only half the time required by motor-carrier personnel. This is because they know their own equipment better, having a better understanding of the part receiving plays in the total concept of the distribution center, and know the methods used by the distribution center to accomplish its purpose.

LOADING SYSTEMS

Competition among the several systems for handling unit loads has forced proponents of each system to work on strengthening the weak points of his system. The following analysis of the unit-load systems now in use throughout the food industry is based on what is actually being done. Three general systems are in use: wooden pallets, slip sheets, and clamp trucks (table 3).

Table 2.—*Summary of rail and truck shipments for the different methods of unitization*

Unitizing Method	Measures	Rail		Truck	
		No.	*Percent*	*No.*	*Percent*
FL	Shipments	438	61.8	1,094	54.6
	Pieces	621,144	55.1	1,069,359	52.6
	Weight in pounds	19,328,109	55.8	29,496,427	51.7
	Man-hours of labor	3,318	75.4	4,582	71.1
WP	Shipments	96	13.5	698	35.5
	Pieces	158,038	14.0	722,423	35.6
	Weight in pounds	4,751,690	13.8	21,513,562	37.8
	Man-hours of labor	294	6.6	1,283	20.0
WP/FL	Shipments	29	4.1	134	6.7
	Pieces	52,665	4.7	162,152	8.0
	Weight in pounds	1,666,640	4.8	4,052,626	7.1
	Man-hours of labor	119	2.8	392	6.0
SS	Shipments	60	8.5	8	.5
	Pieces	118,811	10.5	9,133	.4
	Weight in pounds	3,827,517	11.0	224,982	.4
	Man-hours of labor	182	4.2	23	.3
SS/FL	Shipments	80	11.3	11	.5
	Pieces	171,178	15.2	15,153	.7
	Weight in pounds	4,876,976	14.0	418,956	.7
	Man-hours of labor	446	10.0	59	.9
CT	Shipments	—	—	30	1.5
	Pieces	—	—	22,325	1.1
	Weight in pounds	—	—	778,182	1.4
	Man-hours of labor	—	—	25	.4
CT/FL	Shipments	6	.8	15	.7
	Pieces	5,982	.5	31,503	1.6
	Weight in pounds	201,603	.6	518,609	.9
	Man-hours of labor	43	1.0	79	1.3

Pallet System

The wooden pallet makes possible a system that is simple to operate for both shipping and receiving, is low in cost, and can be used efficiently by producer, distributor, and retailer. The wooden pallet can be handled with all standard types of materials-handling equipment, and no special training of operators is needed.

Table 3.—*Summary of rail and truck shipments for the five product groups, by method of unit-load handling*

Product group	Handling method[1]	RAIL						TRUCK					
		Shipments	Distribution centers	Pieces handled		Weight handled		Shipments	Distribution centers	Pieces handled		Weight handled	
				Average	CV[2]	Average	CV[3]			Average	CV[2]	Average	CV[3]
		No.	*No.*	*No.*	*%*	*1,000 lbs.*	*%*	*No.*	*No.*	*No.*	*%*	*1,000 lbs.*	*%*
I	FL	181	10	739	41	28.5	37	104	8	505	50	16.7	48
	WP	23	6	723	56	37.6	50	13	4	448	28	23.5	51
	WP/FL	5	3	1,181	13	63.5	28	—	—	—	—	—	—
	SS	2	1	768	—	34.3	—	—	—	—	—	—	—
	CT/FL	3	3	808	55	23.0	58	1	1	400	—	12.5	—
II	FL	85	8	1,984	47	38.2	44	169	9	1,011	60	19.0	66
	WP	42	8	2,043	61	44.0	47	80	6	1,228	64	22.4	53
	WP/FL	15	5	1,788	54	46.7	44	15	5	1,718	64	22.4	50
	SS	6	2	1,245	47	27.5	18	—	—	—	—	—	—
	SS/FL	24	7	1,848	62	32.8	30	2	1	1,992	31	40.5	60
	CT/FL	1	1	1,897	—	46.3	—	1	1	1,700	—	26.3	—
III	FL	93	10	1,892	42	61.9	48	269	10	928	44	29.1	38
	WP	13	3	1,879	24	68.8	23	305	10	1,012	40	33.4	32
	WP/FL	6	3	2,346	26	83.0	19	39	7	1,743	28	29.9	40
	SS	42	7	2,067	27	70.8	24	5	4	1,045	38	27.3	33
	SS/FL	31	7	2,546	34	82.1	26	3	1	2,024	48	65.2	2
	CT	—	—	—	—	—	—	1	1	450	—	24.8	—
IV	FL	21	7	2,410	54	60.8	34	222	10	1,188	59	29.0	40
	WP	6	5	1,658	65	46.6	31	163	9	1,185	61	29.6	38
	WP/FL	1	1	2,204	—	60.0	—	50	5	1,537	68	30.2	37
	SS	1	1	1,042	—	46.0	—	2	2	1,610	24	30.4	1
	SS/FL	4	1	2,189	25	71.9	6	4	2	1,249	15	24.8	44
	CT/FL	—	—	—	—	—	—	10	4	2,609	58	37.2	22
V	FL	58	8	1,443	58	57.2	37	330	10	1,002	39	31.1	36
	WP	12	6	1,678	28	72.2	27	137	9	813	36	32.3	37
	WP/FL	2	2	1,830	10	45.1	29	30	5	1,006	39	34.7	26
	SS	9	3	2,457	34	63.6	24	1	1	690	—	27.5	—
	SS/FL	21	6	1,807	46	56.0	21	2	—	551	52	21.6	47
	CT	—	—	—	—	—	—	29	—	754	30	25.8	24
	CT/FL	2	1	830	—	43.2	—	3	—	1,105	32	36.1	27

[1]FL = floor loaded. WP = entire load on wooden pallets. SS = entire load on slip sheets. CT = entire load in clamp blocks. WP/FL = part of load floor-loaded. SS/FL = part of load floor-loaded. CT/FL = part of load floor-loaded.
[2]Coefficient of variation = standard deviation divided by mean times 100.
[3]Weight of pallets not included.

In using wooden pallets, the weight of the pallet and the space it requires are important considerations in handling product group I (paper products) and product group II (low-density items), especially when a standard 40-foot 6-inch boxcar is used. For products groups III, IV, and V the carrier's equipment (except for some of the 100,000-pound cars for product group III) had space enough to absorb the wooden pallets and still attain minimum weight. In 76 percent of the cars carrying mixed loads of all product groups, space was also sufficient to accommodate the pallets.

Pallet quality is important. The species of wood used, the quality of individual parts, the design of the pallet, and the precision of construction are some of the quality considerations.

The food industry has adopted a standard pallet size and specification. The pallet constructed of class C (high-density) hardwood lumber is not readily available to the industry on the West Coast and in the South. The softwood lumber (Douglas-fir, hemlock, larch, and southern pine) is not accepted as equal to the hardwood lumber pallet for use in the pallet-exchange program.

ADVANTAGES

1. The load can be handled from all four sides. This permits maximum use of the floor area of rail and truck equipment.

2. Two pallet loads may be handled as one load. This permits double-decking in the cars and trailers. Two short loads are preferred to one high load, because the short loads are consistent with rack clearances and with stack heights convenient for order selecting.

3. Less time is consumed in checking. When goods are properly palletized, checking is reduced to counting pallet loads. To realize this saving, distribution centers must order in full layer units, which is entirely feasible.

4. Damage to goods in transit can be reduced by 73 percent. To attain this saving, pallet patterns and package dimensions must be designed so that the cases can be well interlocked on the pallet. Additional savings result from elimination of dunnage materials.

5. Demurrage charges can be reduced because unloading times can be reduced from the 6 to 14 hours required for floor-loaded cars to ½ to 2 hours for palletized cars.

6. Condition of the stock is improved because the individual cases are handled only when loaded on the pallet and when selected for shipment to the retail store.

7. Use of pallets permits 100-percent unitization of the carrier equipment because unit loads on wooden pallets can be placed in the doorway of the rail car.

8. Use of pallets permits the use of all conventional types of hand and powered forklift equipment.

9. Less training is required for personnel. This is an important advantage that results from the simplicity of the conventional forklift truck compared to materials-handling equipment with special attachments that require more skill and judgment on the part of the operator.

10. More personnel can operate conventional forklift equipment. Because of the simplicity of the system, it is relatively easy for the distribution center to assign new operators when the regular operators are absent.

11. Unit loads on wooden pallets can be handled easily on motor-carrier equipment.

12. Palletization is the only system that can be employed in a total concept approach from receipt of raw material by the manufacturer through all steps to the retail store, where merchandise may be sold directly from the pallet.

DISADVANTAGES

1. Pallets take up space in the carrier equipment—6 percent in 60-foot cars and 7 percent in 50-foot cars.

2. Pallets must be replaced or returned.

3. A serious disadvantage at present results from the exchange of pallets of different quality. A system of policing and certification is needed.

4. Pallets must be repaired. It is more economical for a distribution center to make repairs than to send pallets out for repair.

5. The reserve pallets needed for an exchange program take up space in the warehouse.

6. The initial investment cost for pallets is higher than the initial cost for other unit-loading systems. But at the same time the initial investment for handling equipment is less.

Slip-Sheet System

Slip sheet is a general term used for both the pull-pak and push-pak methods of unit-load handling. This is a sound materials-handling system, but difficult to apply in day-to-day operations because it requires specially trained personnel and special equipment.

For example, not enough carload shipments are received daily on slip sheets to warrant keeping a multi-tine attachment permanently on a forklift truck. The changeover time commonly takes ½ hour under normal operating conditions.

The multi-tine attachment, combined with the weight of the product, necessitates use of a 5,000-pound capacity forklift truck. This equipment is more difficult to maneuver in a rail car, and receivers are reluctant to take the responsibility for using it in common carrier motor vehicles because of the weight.

The cost of the slip sheet is borne wholly by the supplier even though the benefits are received by supplier, carrier, and receiver.

The cost of 20 to 30 cents for the bottom slip sheets and 30 to 96 cents for the in-between slip sheets makes it very costly for the supplier to use this method, although it can still be cheaper than piece handling.

More than one-half of the cars double-decked with slip sheets required hand unloading of the second deck. The weight of the second stack depresses the in-between slip sheet so that the multi-tine forks cannot enter without damaging the product. When a distribution center purchases the pull-pak attachment, it must also purchase longer tines for the forklift truck to accommodate the 4-inch width of the gripper bar.

The heavier fiberboard slip sheet, substituted for the lighter sheet that tore when the gripper bar pulled it, has created a new problem. Unless the load is slightly raised before the gripper bar is actuated, the forklift truck will be pulled into the load. This happens especially in product group 3 when the unit load weighs 2,000 pounds or more, even though the brakes are set on the

forklift truck (4,000-pound capacity). Unless this problem is corrected through training or modification of slip-sheet design, a 5,000-pound truck will be needed for handling product group III or V packages with the gripper-bar attachment.

ADVANTAGES

1. There is neglible loss of space and weight. This is important in carload shipments of low-density items.
2. Checking or tallying cost is reduced because a unit load count can be employed instead of a piece count.
3. Damage to product can be reduced by as much as 62 percent.
4. Demurrage charges are reduced by reducing the time required to unload the car. Slip sheets were used most extensively for product group 3, where a time saving of 4 to 8 hours per carload was attained.
5. Stock condition is improved because less handling of pieces is required.
6. There are no problems of accountability, return, exchange, or repair because the slip sheets are used only once.
7. Initial investment cost for slip sheets is less than that for pallets, but the investment for handling equipment is greater.

DISADVANTAGES

1. The load can be handled from only one side.
2. Handling two unit loads at the same time is not possible. Twice as many lifts are required to unload double-decked loads as with pallets.
3. Unit loads utilize less of the rail car capacity because the multi-tine equipment, with its longer tines, needs more maneuvering space.
4. Checking time is increased for shipments of mixed lots of products because the products are not normally separated with slip sheets.
5. Slip-sheet systems do not permit efficient use of the forklift equipment because the conventional 2-tine attachments must be removed and replaced with special 6-tine attachments. This requires about $\frac{1}{2}$ hour for each changeover.

6. Personnel require more training to operate the equipment efficiently.

7. When trained personnel are absent, it is more difficult to assign replacement personnel because the equipment is more complex.

8. The equipment needed for handling slip sheets is too heavy for some motor-carrier equipment.

9. Slip sheets are not adaptable to a total concept approach. This is one of the most critical disadvantages. The push-pak and pull-pak systems are more successful when operated between a manufacturers' plant and his own distribution center. There are too many daily operating problems at food distribution centers to permit these systems to operate efficiently on a consistent day-to-day basis. The manufacturer has the problem of making a system efficient only within his own operation. The food-distribution center has the problem of operating a system that will handle a variety of products from over 500 manufacturers.

Clamp-Truck System

ADVANTAGES

Clamp-truck handling has one outstanding advantage: it eliminates both wooden pallets and slip sheets for a variety of products.

DISADVANTAGES

There are a number of disadvantages that must be overcome before this system can begin to provide savings like those already being provided by the wooden-pallet and slip-sheet systems.

1. The product must be center-loaded in the motor carriers' equipment to provide clamping space on both sides. The greatest danger in center loading is damage to the product from shifting loads. Experiments are now being conducted to eliminate this problem.

2. The unit load must be square (each layer to one another), otherwise cases are dropped when the load is picked up.

3. Many products require cooling in storage. Use of the clamp system does not permit any voids in the unit block.

4. The carton walls must be strengthened to avoid collapse while in storage. When the products are stacked 16 to 18 feet high, the carton must have the ability to withstand such loads under adverse humidity conditions. The collapse of stacked merchandise was noted at three different times because of this problem.

5. The drivers of forklift trucks with clamp attachments must be trained to regulate pressure controls. The modern machine has three settings, but the drivers seldom change these settings as they should and when they should.

6. There is a reluctance to use the clamp truck on motor carrier equipment because of its weight.

RAIL SHIPMENTS

Product Group I

Paper products shipped by rail represented the largest movement of shipments to a distribution center (30.2 percent), yet represented only 14 percent of the pieces and 19 percent of the

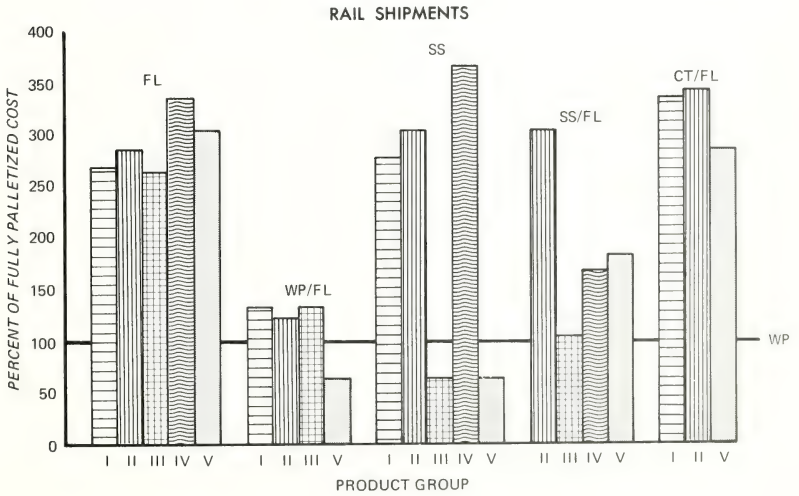

Figure 2.—A comparison of direct labor costs for unloading rail shipments, by product group and handling method. Cost for fully palletized loads is used as a basis (100 percent) for comparison. WP = wooden pallet, FL = floor-loaded, SS = slip sheet, CT = clamp truck.

Table 4.—*Rail shipments of paper products (product group I), by handling method*

Item	FL	WP	WP/FL	SS	SS/FL	CT	CT/FL	Total
				PERCENT OF PRODUCT GROUP				
Shipments	84.7	10.7	2.3	0.9	—	—	1.4	100.0
Pieces	83.5	10.4	3.7	.9	—	—	1.5	100.0
Weight	79.5	13.4	4.9	1.1	—	—	1.1	100.0
Man-hours	90.7	4.3	2.0	1.1	—	—	1.9	100.0
				PERCENT OF TOTAL RAIL SHIPMENTS				
Shipments	25.5	3.2	.7	—	—	—	—	30 ?
Pieces	11.9	1.5	.5	—	—	—	—	14.3
Weight	14.9	2.5	.9	—	—	—	—	18.7
Man-hours	25.0	1.9	.5	—	—	—	—	27.6
				AVERAGES				
Cases/car	743.0	723.0	1,180.0	768.0	—	—	808.0	—
Pounds/case	38.2	52.0	53.7	44.6	—	—	28.4	—
Tons/car	14.1	18.7	31.6	17.1	—	—	11.4	—
				PRODUCTIVITY				
Man-hours/car	6.0	2.3	4.8	6.5	—	—	8.0	—
Tons/man-hour	2.3	8.2	6.5	2.6	—	—	1.6	—
Cases/man-hour	122.0	319.0	245.0	118.0	—	—	101.0	—
				LABOR COST				
Dollars/car	18.0	6.9	14.4	19.5	—	—	24.0	—
Dollars/ton	1.3	.4	.5	1.1	—	—	2.1	—
Cents/case	2.4	.9	1.2	2.5	—	—	3.0	—

total weight received. However, 28 percent of the total labor cost was used to handle this product at the receiving end, because 85 percent of the shipments are still floor-loaded.

Of the 214 carloads audited, the least cost per case handled was for shipments fully unitized on wooden pallets (fig. 2 and table 4). For 23 carloads from 8 paper products manufacturers to 6 distribution centers receiving unit loads via this method, unloading time ranged from 35 minutes per car to 2 hours 40 minutes per car. Compared to piece handling, this unitized handling yielded a saving of $11.10 per car. Unit-load handling systems other than pallets employed in this product group required more man-hours per car than floor-loaded shipments.

The average weight per case in this product group was 40.2 pounds. The range was from 28 to 54 pounds per case.

Product Group II

About half the shipments of low-density products were unitized loads, of which about 75 percent were on wooden pallets (table 5). The average cost of $10.50 per car was equal for handling both partially and fully palletized loads because relatively few cases were floor-loaded in the doorway. The cost per ton was slightly higher and cost per case was slightly less for the fully palletized cars.

In this low-density product group, net weight per carload was less than 30,000 pounds for 40 percent of the floor-loaded cars, for 20 percent of the palletized cars, and for 50 percent of the cars unit-loaded on slip sheets.

The average cost of unloading the 85 floor-loaded cars was $25.80. The saving per car was $15.30 for both the 42 fully

Table 5.—*Rail shipments of low density products (product group II) by handling method*

Item	FL	WP	WP/FL	SS	SS/FL	CT	CT/FL	Total
				PERCENT OF PRODUCT GROUP				
Shipments	49.1	24.3	8.7	3.5	13.8	—	0.6	100.0
Pieces	48.9	26.4	8.3	2.3	13.6	—	.5	100.0
Weight	47.8	27.2	10.3	2.4	11.6	—	.7	100.0
Man-hours	63.3	12.8	4.5	3.2	15.2	—	1.0	100.0
				PERCENT OF TOTAL RAIL SHIPMENTS				
Shipments	11.9	5.9	2.1	.8	3.4	—	—	24.4
Pieces	14.1	7.6	2.4	.7	4.0	—	—	28.8
Weight	9.4	5.3	2.0	.5	2.3	—	—	19.6
Man-hours	16.6	3.4	1.9	.8	4.0	—	—	26.2
				AVERAGES				
Cases/car	1,873.0	2,043.0	1,788.0	1,234.0	1,847.0	—	1,897.0	—
Pounds/case	20.4	21.5	26.1	22.1	17.7	—	24.4	—
Tons/car	19.1	21.9	23.3	13.6	16.3	—	23.1	—
				PRODUCTIVITY				
Man-hours/car	8.6	3.5	3.5	6.3	7.2	—	10.7	—
Tons/man-hour	2.2	6.2	6.7	2.2	2.3	—	2.1	—
Cases/man-hour	218.0	579.0	506.0	201.0	254.0	—	172.0	—
				LABOR COST				
Dollars/car	25.8	10.5	10.5	18.9	21.6	—	32.1	—
Dollars/ton	1.4	.5	.4	1.4	1.3	—	1.4	—
Cents/case	1.4	.5	.6	1.5	1.5	—	1.7	—

palletized and the 15 partially palletized cars. The saving per car was $6.90 for the 6 cars fully unitized on slip sheets and $4.20 for the 24 cars partially unitized on slip sheets.

Product Group III

Unit-load shipments of canned goods increased substantially in 1965 over 1964. In this product group 23 percent of the shipments were fully unitized on slip sheets compared to 7 percent on wooden pallets, and 17 percent were partially unitized on slip sheets compared to 3 percent on wooden pallets (table 6).

Direct labor cost per case handled on slip sheets was 40 percent less than the cost per case handled on wooden pallets. This reflects the experience that has been gained both at shipping and receiving levels in handling single-decked slip-sheet unit

Table 6.—Rail shipments of canned goods (product group III), by handling method

Item	FL	WP	WP/FL	SS	SS/FL	CT	CT/FL	Total
				PERCENT OF PRODUCT GROUP				
Shipments	50.3	7.0	3.2	22.7	16.8	—	—	100.0
Pieces	45.9	6.6	3.7	22.6	21.2	—	—	100.0
Weight	46.9	6.8	3.9	22.5	19.9	—	—	100.0
Man-hours	70.8	4.1	3.2	9.4	12.5	—	—	100.0
				PERCENT OF TOTAL RAIL SHIPMENTS				
Shipments	13.1	1.8	.9	5.9	4.4	—	—	26.1
Pieces	15.6	2.3	1.3	7.7	7.2	—	—	34.0
Weight	17.8	2.6	1.4	8.6	7.6	—	—	38.0
Man-hours	17.9	1.0	.8	2.4	3.2	—	—	25.2
				AVERAGES				
Cases/car	1,892.0	1,963.0	2,346.0	2,301.0	2,628.0	—	—	—
Pounds/case	35.0	35.0	35.3	34.3	32.2	—	—	—
Tons/car	33.1	34.3	41.4	39.4	42.3	—	—	—
				PRODUCTIVITY				
Man-hours/car	8.4	3.5	6.0	2.6	4.5	—	—	—
Tons/man-hour	3.9	9.7	6.9	14.8	9.4	—	—	—
Cases/man-hour	223.0	555.0	391.0	833.0	590.0	—	—	—
				LABOR COST				
Dollars/car	25.2	10.5	18.0	7.8	13.5	—	—	—
Dollars/ton	.8	.3	.4	.2	.3	—	—	—
Cents/case	1.3	.5	.7	.3	.5	—	—	—

loads. Fewer new shippers were using slip sheets in 1965 than were using the wooden pallet-exchange program.

Because shippers in this product group have more experience in using the several methods of unit-load handling, the canned-goods group reflected the least handling cost per case of all five product groups. The cost per case of 1.3 cents for floor-loaded shipments — compared to the costs of 0.6 cent for partially unitized shipments and 0.4 cent for fully unitized shipments — shows that part of the long-sought savings in unit-load handling are beginning to materialize.

For the 185 carloads audited in this group, average weight per car for all unitized shipments exceeded that for floor-loaded cars. This confirms the belief that unit loads do not require more space than floor-loaded shipments. Efficient use of the carrier's equipment depends upon the size of the order rather than on the capacity of the equipment.

Product Group IV

Products in glass comprised only about 5 percent of the total rail shipments; so only 33 cars were audited. Two of the methods of handling—fully unitized on slip sheets and partially unitized on pallets—were represented by only one shipment each. Only 34 percent of the shipments were unitized, of which 60 percent were fully palletized and 30 percent were partially unitized on slip sheets (table 7). Most products of this group can be handled more efficiently on pallets because the products are dense and the containers are fragile.

The average labor cost for handling floor-loaded cars was $26.40. Savings per car of $20.40 were attained for fully palletized cars and $14.40 for cars partially unitized on slip sheets.

The number of unitized shipments of heavy packaged goods increased substantially. At the end of 1965, 44 percent of the shipments were unitized. Most of this increase was in cars partially unitized on slip sheets.

Table 7.—*Rail shipments of products in glass (product group IV), by handling method*

Item	FL	WP	WP/FL	SS	SS/FL	CT	CT/FL	Total
				PERCENT OF PRODUCT GROUP				
Shipments	63.6	18.2	3.0	3.0	12.1	—	—	100.0
Pieces	69.8	13.7	3.0	1.4	12.1	—	—	100.0
Weight	65.5	14.3	3.1	2.4	14.7	—	—	100.0
Man-hours	84.6	5.6	.5	2.1	7.2	—	—	100.0
				PERCENT OF TOTAL RAIL SHIPMENTS				
Shipments	3.1	.8	—	—	.6	—	—	4.6
Pieces	4.5	.9	—	—	.8	—	—	6.5
Weight	3.7	.8	—	—	.8	—	—	5.6
Man-hours	4.2	.2	—	—	.4	—	—	5.0
				AVERAGES				
Cases/car	2,409.0	1,658.0	2,204.0	1,042.0	2,188.0	—	—	—
Pounds/case	25.2	28.1	27.2	44.0	32.8	—	—	—
Tons/car	30.3	23.2	30.0	22.9	35.8	—	—	—
				PRODUCTIVITY				
Man-hours/car	8.8	2.0	1.2	4.6	4.0	—	—	—
Tons/man-hour	6.4	11.6	25.7	4.7	8.9	—	—	—
Cases/man-hour	273.0	828.0	1,889.0	226.0	547.0	—	—	—
				LABOR COST				
Dollars/car	26.4	6.0	3.5	13.8	12.0	—	—	—
Dollars/ton	.9	.2	.1	.6	.3	—	—	—
Cents/case	1.0	.3	.2	1.1	.5	—	—	—

Product Group V

Many of the unit loads on slip sheets were moved in the standard 40-foot 6-inch box cars, and little or no damage to product occurred because of the destiny of the items (flour and sugar mostly) and the interlocking of the packages (bags) permitted very little shifting in transit. The average weight of the cars fully unitized exceeded the weight carried in the floor-loaded cars, providing further evidence that the size of the order and not the capacity of the equipment dictates the efficiency in use of space (table 8).

Only two cars partially unitized in clamp blocks were audited. Because these were both experimental shipments, no conclusions can be drawn.

Table 8.—*Rail shipments of heavy packaged goods (product group V), by handling method*

Item	FL	WP	WP/FL	SS	SS/FL	CT	CT/FL	Total
				PERCENT OF PRODUCT GROUP				
Shipments	56.0	11.5	1.9	8.6	20.1	—	1.9	100.0
Pieces	54.5	10.9	1.9	12.0	19.8	—	.9	100.0
Weight	55.6	13.8	1.4	9.1	18.7	—	1.4	100.0
Man-hours	73.2	5.0	.7	3.4	16.6	—	1.1	100.0
				PERCENT OF TOTAL RAIL SHIPMENTS				
Shipments	8.2	1.7	—	1.3	3.0	—	—	14.7
Pieces	9.0	1.9	—	2.0	3.3	—	—	16.4
Weight	10.0	2.5	—	1.7	3.7	—	—	18.1
Man-hours	11.7	.8	—	.6	2.7	—	—	16.0
				AVERAGES				
Cases/car	1,736.0	1,677.0	1,830.0	2,457.0	1,742.0	—	830.0	—
Pounds/case	34.5	42.9	24.6	25.8	32.1	—	52.0	—
Tons/car	29.9	35.9	22.5	31.6	27.9	—	21.5	—
				PRODUCTIVITY				
Man-hours/car	8.9	2.9	2.4	2.7	5.6	—	4.0	—
Tons/man-hour	3.3	2.3	9.0	11.9	5.0	—	5.3	—
Cases/man-hour	195.0	575.0	752.0	923.0	312.0	—	201.0	—
				LABOR COST				
Dollars/car	26.7	8.7	7.2	8.1	16.8	—	12.0	—
Dollars/ton	.9	.2	.3	.2	.6	—	.6	—
Cents/case	1.5	.5	.3	.3	.9	—	1.4	—

The labor cost for handling floor-loaded cars was $26.70. Savings of about $18 per car were found for fully unitized shipments on both pallets and slip sheets. However, savings of $19.50 per car on shipments partially unitized on wooden pallets were nearly double the saving for loads partially unitized on slip sheets because a larger number of cases were placed in the doorway of slip-sheet cars. A forklift equipped with slip-sheet attachments needs more space for maneuvering.

MOTOR-CARRIER SHIPMENTS

Product Group I

Paper products shipped by truck represented only 6 percent of total truck shipments. Of the 118 truckloads audited, 88 percent were floor-loaded and 11 percent were fully palletized. In view

of the preponderance of floor-loaded shipments, by both rail and truck, this group offers a greater savings potential than any of the other product groups. Also, the cost per case handled was found to be from 33 percent to 100 percent greater for floor-loaded shipments of this group (2.0 cents) than for the other product groups (1.0 to 1.5 cents). Per-case handling cost was 0.8 percent case for palletized shipments (fig. 3 and table 9).

It is frequently stated that paper products cannot be unitized economically because of the low density of the products, which requires that the total space in the carrier equipment be utilized. It was found that nearly 75 percent of the floor-loaded shipments did not utilize 90 percent of the available space anyhow.

One manufacturer of paper products who kept records of 8 palletized shipments via motor carrier found that the average weight was 12.3 tons, the average unloading time was 55 minutes

Figure 3.—A comparison of direct labor costs for unloading truck shipments, by product group and handling method. Cost for fully palletized loads is used as basis (100 percent) for comparison.

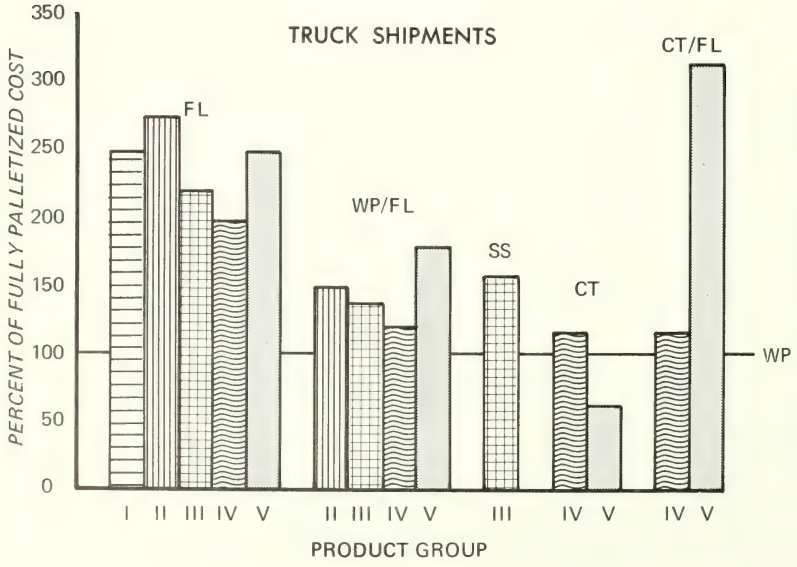

Table 9.—*Truck shipments of paper products (product group I), by handling method*

Item	FL	WP	WP/FL	SS	SS/FL	CT	CT/FL	Total
				PERCENT OF PRODUCT GROUP				
Shipments	88.1	11.1	—	—	—	—	0.8	100.0
Pieces	89.4	9.9	—	—	—	—	.7	100.0
Weight	84.5	14.9	—	—	—	—	.6	100.0
Man-hours	94.7	4.4	—	—	—	—	.9	100.0
				PERCENT OF TOTAL TRUCK SHIPMENTS				
Shipments	5.2	.7	—	—	—	—	—	5.9
Pieces	2.6	.2	—	—	—	—	—	2.9
Weight	3.0	.3	—	—	—	—	—	3.6
Man-hours	5.6	.3	—	—	—	—	—	5.9
				AVERAGES				
Cases/truck	505.0	448.0	—	—	—	—	—	—
Pounds/case	32.9	52.4	—	—	—	—	—	—
Tons/truck	8.3	11.7	—	—	—	—	—	—
				PRODUCTIVITY				
Man-hours/truck	3.4	1.2	—	—	—	—	—	—
Tons/man-hour	2.4	1.7	—	—	—	—	—	—
Cases/man-hour	146.0	342.0	—	—	—	—	—	—
				LABOR COST				
Dollars/truck	10.2	3.6	—	—	—	—	—	—
Dollars/ton	1.2	.3	—	—	—	—	—	—
Cents/case	2.0	.8	—	—	—	—	—	—

(45 to 61 minutes), and average unloading cost was $2.70 as compared to $10.20 for the average floor-loaded truck.

A recent survey by the Truck Trailer Manufacturers Association showed that 85 percent of the motor carrier equipment being manufactured is at least 40 feet long and has height and width sufficient to double-deck 48-inch by 40-inch pallet loads.

Product Group II

Thirty-seven percent of the 267 shipments of low-density items were in unit loads, of which 97 percent were on wooden pallets. The 80 truckloads fully palletized averaged 0.4 cent labor cost per case handled, compared to the cost of 1.1 cents for handling floor-loaded shipments (table 10).

Table 10.—*Truck shipments of low-density items (product group II), by handling method*

Item	FL	WP	WP/FL	SS	SS/FL	CT	CT/FL	Total
				PERCENT OF PRODUCT GROUP				
Shipments	63.1	30.1	5.7	—	0.7	—	0.4	100.0
Pieces	56.9	32.8	8.7	—	1.0	—	.6	100.0
Weight	59.5	32.3	6.2	—	1.5	—	.5	100.0
Man-hours	75.4	16.5	6.4	—	.9	—	.8	100.0
				PERCENT OF TOTAL TRUCK SHIPMENTS				
Shipments	8.4	4.1	.8	—	—	—	—	13.3
Pieces	8.4	4.8	1.2	—	—	—	—	14.7
Weight	5.7	3.0	.6	—	—	—	—	9.5
Man-hours	10.1	2.2	.9	—	—	—	—	13.4
				AVERAGES				
Cases/truck	1,023.0	1,228.0	1,717.0	—	—	—	—	—
Pounds/case	18.8	17.7	13.0	—	—	—	—	—
Tons/truck	9.6	10.8	11.1	—	—	—	—	—
				PRODUCTIVITY				
Man-hours/truck	3.9	1.7	3.6	—	—	—	—	—
Tons/man-hour	2.4	6.1	3.0	—	—	—	—	—
Cases/man-hour	262.0	692.0	468.0	—	—	—	—	—
				LABOR COST				
Dollars/truck	11.7	5.1	10.8	—	—	—	—	—
Dollars/ton	1.2	.5	1.0	—	—	—	—	—
Cents/case	1.1	.4	.6	—	—	—	—	—

Product Group III

Canned goods represented the largest movement via motor carrier to distribution centers—31.3 percent of the total products delivered by truck. Approximately 60 percent of the shipments were unitized, of which almost 98 percent were palletized. The cost per case for handling palletized loads was less than half the cost for handling floor-loaded shipments. Per-case handling costs for direct labor were 0.5 cent for palletized loads, 0.8 cent for slip sheets, and 1.1 cents for floor-loaded shipments (table 11).

Table 11.—*Truck shipments of canned goods (product group III), by handling method*

Item	FL	WP	WP/FL	SS	SS/FL	CT	CT/FL	Total
				PERCENT OF PRODUCT GROUP				
Shipments	42.6	49.8	6.0	0.9	.5	.2	—	100.0
Pieces	40.7	50.8	6.2	.8	.9	.6	—	100.0
Weight	40.0	52.2	6.0	.7	1.0	.1	—	100.0
Man-hours	58.7	32.8	5.8	.9	1.7	.1	—	100.0
				PERCENT OF TOTAL TRUCK SHIPMENTS				
Shipments	13.6	15.7	2.0	—	—	—	—	31.3
Pieces	12.2	15.4	1.9	—	—	—	—	30.1
Weight	13.7	17.9	2.0	—	—	—	—	34.3
Man-hours	15.2	8.5	1.5	—	—	—	—	25.8
				AVERAGES				
Cases/truck	931.0	1,007.0	983.0	1,044.0	—	—	—	—
Pounds/case	31.0	32.7	30.4	26.1	—	—	—	—
Tons/truck	14.6	16.4	14.9	13.6	—	—	—	—
				PRODUCTIVITY				
Man-hours/truck	3.6	1.7	2.5	2.8	—	—	—	—
Tons/man-hour	4.0	9.4	6.0	5.2	—	—	—	—
Cases/man-hour	255.0	573.0	395.0	373.0	—	—	—	—
				LABOR COST				
Dollars/truck	10.8	5.1	7.5	8.4	—	—	—	—
Dollars/ton	.7	.3	.5	.6	—	—	—	—
Cents/case	1.1	.5	.7	.8	—	—	—	—

Product Group IV

Slightly more than 50 percent of the products in glass moved in unit loads. Of the 228 unitized shipments, 60 percent were fully palletized and 22 percent were partially palletized (table 12).

Though this group as a whole accounted for only 5 percent of the total movement audited in the study, the 451 truckloads accounted for 22.5 percent of the total truck shipments. Handling cost for palletized shipments were 0.5 cent per case compared to 1.0 cent for floor-loaded shipments.

This product group was the most susceptible to damage because of the fragile nature of the containers. However, use of proper pallet patterns and loading practices by the manufacturer was the key to reduced damage to goods.

Manufacturers in this group tend to stack their product too

Table 12.—*Truck shipments of products in glass (product group IV) by handling method*

Item	FL	WP	WP/FL	SS	SS/FL	CT	CT/FL	Total
				PERCENT OF PRODUCT GROUP				
Shipments	49.4	36.2	11.1	0.4	0.9	—	2.0	100.0
Pieces	47.4	34.5	12.0	.6	.8	—	4.7	100.0
Weight	48.4	36.3	11.3	.5	.7	—	2.8	100.0
Man-hours	63.2	22.8	8.7	.4	1.2	—	3.7	100.0
				PERCENT OF TOTAL RAIL SHIPMENTS				
Shipments	11.1	8.2	2.5	—	—	—	—	22.6
Pieces	13.2	9.6	3.4	—	—	—	—	27.8
Weight	11.2	8.5	2.6	—	—	—	—	23.4
Man-hours	14.6	5.3	2.0	—	—	—	—	23.1
				AVERAGES				
Cases/truck	1,201.0	1,190.0	1,357.0	1,610.0	1,249.0	—	2,609.0	—
Pounds/case	24.1	24.9	22.2	18.8	19.8	—	14.2	—
Tons/truck	14.4	14.8	15.0	15.2	12.4	—	18.6	—
				PRODUCTIVITY				
Man-hours/truck	4.2	2.1	2.5	3.2	4.4	—	5.5	—
Tons/man-hour	3.4	7.1	5.8	4.7	2.8	—	3.7	—
Cases/man-hour	283.0	572.0	522.0	501.0	286.0	—	499.0	—
				LABOR COST				
Dollars/truck	12.6	6.3	7.5	9.6	13.2	—	16.5	—
Dollars/ton	.9	.4	.5	.6	1.0	—	.8	—
Cents/case	1.0	.5	.6	.6	1.0	—	.6	—

high on a pallet, and this creates leaning loads that seemed to open up in transit and fall to the trailer floor. Even where bracing was supplied, it did not contain the load properly and permitted cases to fall. None of the restraining devices now in use prevent this type of damage; and manufacturers of this kind of equipment could perform a good service by developing effective restraining devices.

Product Group V

Heavy packaged goods provided data on the clamp-truck method of handling unit loads. The 29 shipments in clamp blocks were all from one manufacturer to one distribution center. The labor cost for clamp-truck handling was 0.4 cent per case compared to 0.6 cent for fully palletized shipments. Analysis of

39 fully palletized truckloads shipped by the same manufacturer to 8 distribution centers showed an almost identical relationship (table 13).

The apparent efficiency of the clamp trucks in unloading was due mainly to the fact that there were 20 palletized units single-decked in each truck and only 10 clamp blocks stacked down the center of the truck; so the palletized truckloads required twice as many lifts as the clamp-truck loads. The clamp loads contained 17 percent less weight per truckload.

Damage to products was higher in the trucks loaded in clamp blocks because approximately 2 feet of space was left on each side of the unit blocks. The requirements for a minimum space of 4 to 6 inches between blocks is one of the problems limiting the use of this system. Compatibility with handling requirements,

Table 13.—*Truck shipments of heavy packaged goods (product group V), by handling method*

Item	FL	WP	WP/FL	SS	SS/FL	CT	CT/FL	Total
				PERCENT OF PRODUCT GROUP				
Shipments	61.6	26.6	5.4	.2	.3	5.4	.5	100.0
Pieces	66.1	22.4	6.1	.1	.2	4.4	.7	100.0
Weight	61.6	26.6	6.2	.2	.3	4.5	.6	100.0
Man-hours	80.6	11.7	5.4	.1	.3	1.2	.7	100.0
				PERCENT OF TOTAL TRUCK SHIPMENTS				
Shipments	16.5	7.2	1.5	—	—	1.5	—	26.9
Pieces	16.2	5.5	1.5	—	—	1.1	—	24.5
Weight	18.0	7.8	1.8	—	—	.1	—	29.2
Man-hours	25.7	3.7	1.7	—	—	.3	—	31.8
				AVERAGES				
Cases/truck	998.0	782.0	1,003.0	690.0	551.0	744.0	754.0	—
Pounds/case	31.1	39.5	34.5	40.0	39.2	34.6	32.6	—
Tons/truck	15.5	15.4	17.3	13.8	10.8	12.8	12.2	—
				PRODUCTIVITY				
Man-hours/truck	5.0	1.7	3.6	2.5	3.2	.9	4.8	—
Tons/man-hour	3.1	9.2	4.7	5.5	3.4	15.8	3.6	—
Cases/man-hour	199.0	466.0	274.0	276.0	174.0	926.0	220.0	—
				LABOR COST				
Dollars/truck	15.0	5.1	10.8	7.5	9.6	2.7	14.4	—
Dollars/ton	1.0	.3	.6	.5	.9	.2	1.2	—
Cents/case	1.5	.6	1.1	1.1	1.7	.4	1.9	—

strength of the containers, stacking patterns, weight of equipment, cost of equipment, and attachment changeover time also influence the economics of the system.

The use of the wooden pallet as the major medium for unit-load handling on motor carriers reflects the restriction on the weight of equipment that can be placed in truck trailers. Hand and electric pallet jacks were used in many places, and 3,000- to 4,000-pound forklift trucks with two tines were used for many of the double-decked loads. The multi-tine and clamp attachments weigh considerably more than other pieces of equipment, and may seriously damage the carriers' trailers.

THE VALUE OF A WOODEN-PALLET SYSTEM

Of the systems now in use, the wooden pallet, used in a national pallet-exchange program, has the best chance to provide consistent savings in unit-load handling. In addition to handling products with available conventional equipment, it is the only system that can be used in a total concept approach to:

Carry raw material into a plant.
Move finished goods from production to storage.
Provide the base for order selecting.
Carry the completed order to a shipping area.
Support the load during transportation.
Carry the product to receiving dock at destination.
Hold the product in a reserve or forward storage area.
Form the base for order selecting to retail stores.
Again carry the product to a shipping area.
Support the load through transportation cycle.
Carry the product to its final destination—the retail store.

The analysis of case histories in the application of unit-load handling in a total concept approach showed that savings of 20 cents per case resulted when piece handling systems were converted to palletized systems.

Current statistics provided by the food industry show that 15 billion cases of goods pass through the total food-distribution system annually. At a savings of 20 cents per case, this indicates

a saving of $3 billion per year. This is equivalent to three times the current net profit of the total industry.

Sixty percent of the savings occur in product flow activities, beginning with receipt of raw materials by the manufacturer through to receipt of the finished goods by the retail food store. Forty percent of the savings occur in paper flow activities, beginning with creation of purchase orders by the buyers through to payment of the final invoice. The savings are distributed as shown in the following tabulation:

	Saving *Cents per case*
Manufacturer	
Raw material:	
Receiving	0.6
Moving to storage	.8
Storing	.2
Finished goods:	
Moving to storage	.1
Storing	.0
Selecting	1.0
Shipping	1.1
	3.8
Carrier	
Pickup	.7
Delivering	.7
	1.4
Distribution Center	
Receiving	1.1
Storing	.2
Selecting	1.0
Shipping	1.1
Other	.4
Backhauling	1.4
	5.2
Retail Store	
Receiving	.5
Storing	.4
Pricing	.9
Shelving	.0
	1.8
Total, product flow	12.2
Total, paper flow	7.8
Total saved per case	20.0

It is relatively easy to establish cents per case saved at each cost center in product flow because the pattern of product flow through different companies is consistent.

It is relatively difficult to establish cents per case saved at each cost center in paper flow because of the variety of forms used both within and between companies. However, in any individual company this saving can be determined accurately.

THE VARIABLES IN UNIT-LOAD SYSTEMS

A unit-load handling system has impacts at every cost center all along the line from manufacturer to retailer. To get the full benefit from a unit-load program, one must consider all the many variables.

Few shippers, carriers, and receivers plan and schedule their entry into unit-load handling in enough detail to account for all the variables. As a result, the savings they expect often do not materialize. Many companies concentrate their interest on the loading and unloading, and ignore the impacts that a unit-load system has on other cost centers. The effects of inadequate planning can be seen when the costs for the same type of shipment, handled by different receivers, range widely.

Unit-load handling is affected by:

1. The company policy, methods, personnel practices, physical facilities, equipment, and supervision ratio.
2. Product characteristics and the manner in which the product is loaded at the shipper's plant.
3. The type and condition of the carrier's equipment.

The following list details the various factors that affect any system of unit-load handling in each of the activity locations. The four requirements that have the greatest effect in coordinating or minimizing these variables are:

1. A better understanding of each others' problems.
2. A sincere desire among shipper, carrier, and receiver to cooperate.
3. More supervision by men trained to supervise rather than oversee.

4. A standard, for the entire industry, to measure performance in many of the activity areas.

The variables can be grouped by classes as follows:

Administrative Variables

Major areas in which profits and pitfalls can occur are often overlooked. They should be carefully controlled. To be successful, any program of unitized handling must be tempered with the many variables in real-life operation. Some of the factors most frequently overlooked in the process of installing unitized handling systems are listed below. Too often these functions are still geared to piece handling while the unloading and loading functions are unitized.

Accounting treatment
Assignment of personnel
Buyer cooperation
Coffee breaks
Control reports
Customs
Employee attitudes
Employee rating procedures
Freight allowances
Housekeeping
Packaging
Paperwork flow
Physical facilities
Smoking rules
Split shifts
Supervision
Traffic operations
Training
Type of equipment
Unions
Use of private carrier
Weather

Paperwork at the manufacturer's plant and the distribution centers has grown far too complicated and is a major cause of delay in shipping and receiving unit loads. By realigning the flow from the point at which the purchase order is created, the order can be transmitted, processed, filled, shipped, received, and paid for with 60 percent less paperwork than is now being used.

Rail-Dock Variables

Variables relate directly to the receiving system of the distribution center in terms of personnel, equipment, physical properties, and company policy.

	Distribution center							
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Physical properties:								
Number of rail tracks used	1	2	1	1	1	1	1	2
Dock area covered	Yes	No	Yes	Part	Part	Yes	No	Yes
Company policy:								
Cards spotted on tracks used	15	17	15	10	10	12	15	15
All cars unloaded same day	No	Yes	Yes	No	No	No	No	Yes
Doors opened before shift start	No	Yes	Yes	No	No	No	No	Yes
Unloaders get own pallets	Yes	No	No	No	No	No	No	No
Smoking allowed in dock area	Yes	Yes	Yes	No	Yes	No	Yes	Yes
Receive during day/night	D/N	D	N	N	D	D	D	D
Day shift starts	7am	6am	—	4pm	7:30am	8am	7am	7am
Two-shift operation (rail)	Yes	No	Yes	No	No	No	No	No
Equipment used: EWS = Electrical work saver; F/L = Conventional fork lift; W/F = Walkie fork.								
Floor-loaded product	EWS	EWS	EWS	EWS	F/L	EWS	EWS	EWS
Unitized on wooden pallets	W/F	F/L	F/L	F/L	F/L	—	F/L	F/L
Slip sheets, pull pak	Yes	Yes	Yes	No	No	No	No	Yes
Slip sheets, push pak	Yes	Yes	Yes	No	No	No	Yes	Yes
Personnel practice:								
Number men per car — F/L	2	1	1	2	2	1	1	1
W/P	2	1	1	3	1	1	1	1
S/S	3	1	1	—	—	—	—	2
Additional checks & tally	—	1-2	—	1	1	—	1	—

Truck-Dock Variables

Variables directly related to the receiving system of the distribution center in terms of personnel, equipment, physical properties, and company policy.

	Distribution Center							
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Physical properties:								
Number of receiving dock areas	1	3	1	2	1	1	1	3
Number of receiving bays used	18	25	25	12	12	18	24	30
Covered dock area	Yes	No	Yes	No	Yes	Yes	Yes	Yes
Company policy:								
Unit loads unloaded by carrier/ distribution center	DC	C	C	DC	DC	DC	C	DC
Checked/at dock/on truck/in staging area	T	D	SA	D	SA	D	SA	SA
Receiving starts—a.m.	7	6	6	7	7:30	8	7	8:30
Receiving finishes—p.m.	3:30	2:30	2:30	3:30	4:00	4:30	3:30	5:00
Day shift/night shift	D	D	D	D/N	D	D	D	D/N
Equipment used: EWS = Electric work saver; F/L = Conventional fork lift: W/F = Walkie fork.								
Floor-loaded product	F/L	Dolly	EWS	W/F	F/L	EWS	EWS	F/L
Unitized on wooden pallet	F/L	EWS	EWS	W/F	F/L	EWS	EWS	F/L
Slip sheets, multi-tine	X	—	—	—	—	—	—	—
Clamp truck	—	—	X	—	—	—	—	—
Size pallets: 48x40 — 4-way	X	X	X	X	X	X		X
32x40 — 2-way	—	—	—	—	—	—	X	—
48x40 — wing	—	—	—	—	—	—	X	—
40x36	—	—	—	—	—	X	—	—
Personnel practice:								
Number of receiving clerks	3	2	4	4	1	3	3	3
Number of take off men	3	3	0	2	1	2	0	3
Number of put away men	2	3	4	2-3	1-2	2	*	6

*Different type put-away system used.

Physical and Information Flow

AT THE MANUFACTURER

Physical Flow Variables

A B C velocity ratings of products.
Unit package dimensions, capacities, and position in cases.
Pallet load heights and layer patterns.
Case loading, pallet loading, and reloading of pallets for shipment.
Finished goods storage layout.
Order-picking equipment and methods.
Building restrictions evaluation.
Order accumulation for shipment.
Pallet-repair and replacement policies.
Empty pallet removal from rail cars and trailers.
Spotting of rail cars and trailers.
Loading equipment and methods for rail cars and trailers.

Information Flow Variables

Market research.
Market forecasting.
Sales policies and practices.
Order processing procedures.
Production control and planning.
Inventory-control methods and equipment.
Quality-control methods and policies.
Central data-processing systems.
Carrier equipment specification.
Traffic control, rates, and schedules.
Billing methods and procedures.
Damage claim processing.

AT THE CARRIER

Physical Flow Variables

Pool car assignment.
Assignment of specially equipped cars.
Specification of rail car and trailer dimensions.

Planning for carload, less than carload, truckload, and less than truckload shipments.
Private cartage.

Information Flow Variables

Freight allowances.
Demurrage and detention.
Damage-claim processing.
Fleet scheduling.

AT THE WHOLESALER-DISTRIBUTOR

Physical Flow Variables

Spotting of rail cars and trailers.
Preparing for unloading.
Unloading equipment and methods for rail cars and trailers.
Empty pallet replacement in rail cars and trailers.
Clean-up of cars and trailers.
Reloading pallet loads to fit storage racks.
Movement to storage and segregation of items.
Empty pallet storage.
Pallet repair and replacement.
Housekeeping.
Order-picking.
Order assembly and staging.
Truck loading for delivery to retail store.

Information Flow Variables

Data processing.
Inventory control and re-order points.
Order processing.
Received order entry.
Billing and paying.
Delivery scheduling.
Damage-claim processing.

AT THE STORE DELIVERY CARRIER

Physical Flow Variables

Private cartage.
Motor freight carrier.
Cargo space specification.

Information Flow Variables

Route scheduling.

AT THE RETAILER

Physical Flow Variables

Truck and trailer unloading equipment and methods.
Empty pallet return.
Segregation of product for stock or storage.
Replenishment.
Pricing and price marking.

Information Flow Variables

Order preparation.
Receiving order checking.
Price checking.
Shelf-space analysis.

Handling Variables

FLOOR-LOADED SHIPMENTS

Including floor-loaded portions of partially unitized shipments

1. Shifting of cases in transit often requires the use of a crowbar to unload.

2. Removal of cases from the doorway in shipments of product groups I and II often requires either that the top cases be pried under the doorway and dropped, or pulled with some type of hook device, or with the assistance of a second man. Product groups I, II, IV, and V necessitate either building a platform of pallets raised by an electric work saver for the unloader to stand on, or the assistance of a fork truck operator to raise the unloader to the top of the load.

3. Color coding of items facilitates the locating of items and thus avoids mistakes in building a load, and then the need to tear it down and rebuild it.

4. Vertical alignment of items, as opposed to horizontal alignment, facilitates unloading by making it easier for the unloaders to reach cases of an item.

5. Locating the entire quantity of an item in the same place in the car or truck eliminates the need to build a partial load,

remove it until other items are unloaded, and return again to complete the load.

6. Block-loading hinders unloading, especially when the block is high. Items in product groups I and II, when loaded on slip sheets or in clamp blocks to the roof of the carriers' equipment, present a hazard because the block may fall when the pallet pattern is broken in manual unloading. Workmen are hesitant when unloading such shipments and consequently the process is delayed. Items in product groups III, IV, and V are usually smaller and it is difficult to remove them from the far side of a block; and because they are heavy, it is difficult to remove them when they are interlocked with cases on the layer above.

7. Product damage causes lost time in cleaning up, checking wet or creased cases for the presence of additional damage, avoiding odors (vinegar, bleach, ammonia, decay), avoiding slick spots on the floor, and removing cases stuck to each other.

8. Gluing cases together hinders unloading when cases must be handled individually.

9. The use of reefer cars with small doorways and high, rotted rack floors impedes movement of equipment in and out of the car.

10. The use of removable retaining devices increases unloading time because the devices must be removed and stored on the busy receiving dock, and then later must be put back into the car.

11. Loading cases up against the doors, besides damaging products because of the opening and closing of doors, hinders securing the dockplate to the car.

SHIPMENTS ON WOODEN PALLETS

1. Underhang on pallets permits shifting of the load during transit.

2. Not allowing for overhang causes poor alignment at the doorway and allows shifting behind the bulkheads.

3. Not allowing for differences in unit-load heights permits shifting of top layers.

4. Improper use of bulkheads, not closed in proper slots, or side fillers not used to full capacity, will allow shifting.

5. Double-decking unlike items results in double handling

because each pallet must be handled individually instead of two pallets at one time.

6. Double-decking high loads impedes or prevents removal of two pallets at a time.

7. Shipping on broken pallets often requires the transfer of merchandise to another pallet; and in addition the receiver must incur the costs of repair or replacement of the damaged pallet.

SHIPMENTS ON SLIP SHEETS

Slip sheets single-decked or with separators between decks

1. Slip sheet lips often do not show at the front of the load.

2. Cardboard placed on the floor beneath the slip sheets makes it difficult to insert the multi-tines under the load or to pull the slip sheet onto the tines. The chances of damaging the product are increased; and in some refrigerated cars circulation of the cold air is restricted.

3. The cases on the second deck often sag between the separator strips that are often placed between the loads, so that mechanical unloading is virtually impossible.

4. All the conditions necessary to obtain a well-interlocked load on pallets also apply to loads on slip sheets to prevent shifting in transit.

5. The practice of using products as dunnage hinders unloading and requires the use of additional personnel to remove the floor-loaded cases. This practice increases the cost and usurps most of the potential savings. Such loading cannot truly be classed as unitized.

Slip sheets without separators

1. Shippers frequently use lightweight slip sheets, which tear in the process of pulling the load onto the tines of the truck.

2. Loads are often so heavy that the fork truck is pulled into the load instead of the load being pulled onto the fork truck tines.

3. An additional sheet should be placed on top of the first unit load if pull-pak equipment is used to remove the second deck.

4. Cardboard side fillers and center separators that are not properly designed often collapse when cases shift in transit.

Pallet-Pattern Variables

Pallet patterns affect every phase of the system for both the manufacturer and the distributor, because the pattern determines the size, composition, and stability of the unit load. Choice of the right pallet pattern is the most important factor in setting up a pallet-exchange program because distributors and manufacturers must select a pattern that is compatible for both of them; and they must coordinate work methods to speed flow of merchandise between them.

Distributors must write the orders and specify quantities in unit load or full layers of the unit block so that the manufacturer can process the order without reverting to piece handling. Order-picking at both locations can be easy and fast if pallet patterns are designed to be consistent with order quantities and physical facilities. Packages must be sized and shaped to fit the pallet and provide good interlock.

The height of the unit block must be consistent with ceiling heights to utilize the space of the buildings efficiently.

Storage of both raw materials and finished goods at the manufacturer's plant as well as reserve storage and picking-area storage at the distributor is affected by the pallet pattern. Close coordination and compromise is required.

Capital investments by both parties must be carefully analyzed to insure that existing facilities are not rendered obsolete and that new investments are necessary.

Handling equipment at both locations must be considered to insure that the equipment can handle the unit load. Shipping and receiving practices must be coordinated and adjusted to provide minimal cost and maximum efficiency to both parties.

At the manufacturer's plant, pallet patterns affect production planning, scheduling, storing, cooling, production facilities, and warehouse capacity. In assigning pallet patterns to each item in the product line, planning must be detailed and thorough enough to insure compatibility with unitized handling. Paper flow is very often geared to the rate of product flow for piece-handling systems and thus causes delays and increases costs when unitized systems are installed. Freight allowances, demurrage, and deten-

tion charges are affected by the accelerated movement of unit loads. Faster turn-around of carrier's equipment justifies reduced tariff rates and eliminates the costs of holding carrier's equipment at the docks.

At the distributor's plant, stock rotation, inventory systems, and storage facilities are affected by the pallet pattern.

The impacts of these factors on unit-load systems are often underestimated.

OVERS, SHORTS, AND DAMAGE

One of the major benefits expected from unit-load systems of handling food products is a significant reduction in claims for overs, shorts, and damages (OS&D). Records maintained over a period of 27 months on shipments moving in unit loads via the

Figure 4.—Minimal handling costs result from the right carton size, right pallet pattern, correct loading, and correct materials-handling equipment operated properly.

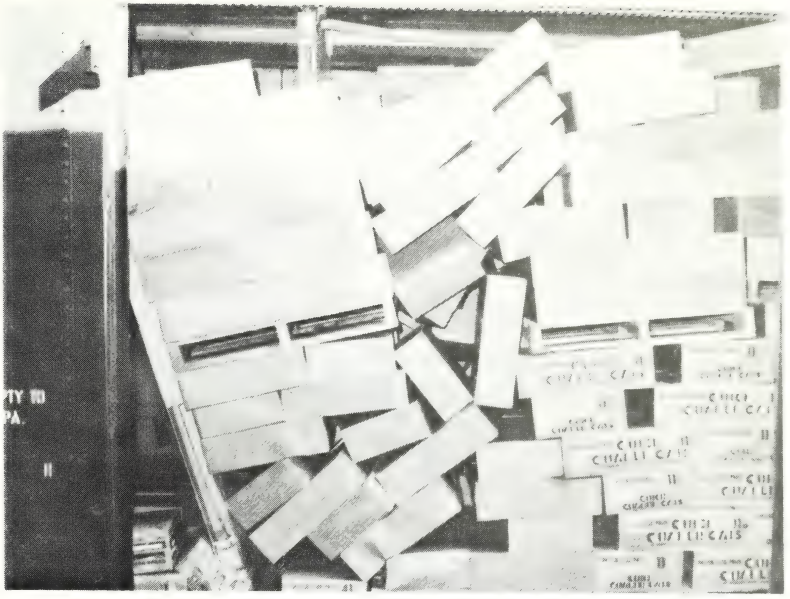

Figure 5.—The load in the doorway of this boxcar has fallen apart, causing damage to the goods. Poor loading methods cause much damage to goods.

several systems used showed that a dramatic reduction in overs, shorts, and damage to product can be attained. For example, claims against the rail carrier have been reduced $132,000 a year at one distribution center.

However, the records also showed that unit-load systems installed without adequate planning and operated by inexperienced personnel resulted more often than not in a dramatic increase in OS&D claims. Three significant findings of this study showed that:

1. Properly planned and executed unit loads in a wooden-pallet-exchange program reduced product claims by 73 percent.
2. Properly planned and executed unit loads in a slip-sheet program reduced product claims by 62 percent (fig. 4).
3. Improperly planned or executed unit loads, in these programs, increased claims 23 to 58 percent beyond that experienced when the same product was floor-loaded (fig. 5).

The specific causes of overs, shorts, and damage were found to be due to poor practices on the part of shippers, carriers, and receivers as noted below.

Poor Practices by Shippers

1. Cases are loaded loose on pallets in car doorways.
2. Bulkhead doors are not latched, are partially latched, or are improperly latched.
3. Incorrect pallet patterns provide poor interlock of cases.
4. Pallets are used as dunnage.
5. Products are used as dunnage.
6. Gluing cases together keeps the goods stacked during transit, but causes considerable damage at subsequent handling stages.
7. Poorly designed packages result in rupture, tearing, and crushing.
8. Paperwork practices designed for piece handling cause errors and delays because the checker cannot keep pace with the rapid flow of products.
9. Poor-quality pallets result in product damage as a result of puncture, tearing, and crushing.
10. Pallet-repair practices materially affect damage, especially where hay-wire practices result in failure during transit.
11. Side fillers are often not extended to provide support to the entire cargo.
12. Slip sheets are often too small, too light, or too heavy, so that the product is damaged in attempting to unload it.
13. Double-decked slip-sheet loads without proper spacers are subject to damage because the handling requires very precise maneuvering of materials-handling equipment.
14. The product is often stacked too high in one unit block so that cases fall off the top or the load falls apart.
15. Overhang of products on the pallet results in crushing, puncturing, and binding of the load so that it cannot be unloaded in units.
16. Underhang of products allows the load to shift on the pallet, resulting in jamming of the load and resultant damage.

17. Placing products, especially product groups III, on slip sheets in trucks requires piece handling to avoid damaging the carrier's equipment.

18. Placing products in clamp blocks in motor carrier equipment may damage the trailer when materials-handling equipment exceeds the structural capacity of the equipment.

19. Attitudes of personnel handling products affect damage directly.

Poor Practices by Carriers

1. The sliding sill on cushion cars is frequently not serviced regularly, resulting in excessive shock.

2. Trailers and cars are not always cleaned properly, resulting in damages to products.

3. The old refrigerator cars with wooden slat floors often have decayed slats so that materials-handling equipment cannot operate.

4. In motor carrier shipments, products improperly stacked will fall in transit and may be seriously damaged.

5. Damage to products often results during switching operations by rail carriers and when trailers are coupled and uncoupled.

6. Doors that do not fit properly result in weather damage to products.

7. Claims for damage are often exaggerated because they are based on inspection by the receiver instead of by the carrier.

8. Switching of partially unloaded cars frequently results in damage to products.

Poor Practices by Receivers

1. The practice of using unloaders to check products at the receiving dock often results in errors.

2. Operators of materials-handling equipment are often inadequately trained.

3. Damage to carrier's equipment at the receiver's dock is caused by careless practices, inadequate training, and improper facilities.

4. The practice of not breaking down loads before switching results in product damage.

5. Poor-quality pallets used in exchange programs cause damage to products.

6. Permitting truck drivers to operate materials-handling equipment frequently results in damage to materials-handling equipment, to products, and to carriers' equipment.

7. Damage claims initiated by unqualified personnel are often erroneous.

8. Attitudes of personnel handling products affect damage directly.

9. Double-decked slip-sheet loads are subject to damage because the handling requires very precise maneuvering of equipment. Proper care is not exercised by drivers in handling these loads.

10. Poor repairs to pallets result in damage to products.

PALLET REPAIRS

Analysis of pallet-repair methods and procedures indicates that both the manufacturers and the distribution centers should repair their own pallets rather than contract for repair or discard the damaged pallets. The initial investment required is about $500. The following equipment is needed:

1. An air-driven power gun to drive screw-type nails. The ability of the power tool to drive the nail in completely with one stroke negates the need for predrilled deckboards and thus reduces the cost of replacement parts.

2. A reel on a balancer arm will be helpful in keeping the air hose off the floor and out of the way of the employee doing the repairs.

3. An oiler to lubricate the equipment will prolong its life and reduce down time. The repairs to the power gun are usually provided at no cost by the supplier, as long as nails are purchased from the same suppliers.

4. Air hoses will normally be about 25 feet long—depending on the physical setup of the repair location.

5. Air compressors are normally available in a maintenance shop. It is strongly recommended that the maintenance group be charged with repairing all pallets at one location. This will cen-

tralize the operation and obviate the need for any accounting allocation—as it can be treated as a maintenance chore in budget and company policy. The practice of having one department repair pallets for another and keep records to charge labor and material costs to other departments is false economy.

6. Space for repairs will usually take 150 to 225 square feet, depending on the volume of pallets repaired. Approximately 200 square feet is adequate space for equipment, materials, and working area for one man to repair 75 pallets daily.

Variable costs will be for nails, labor, and deckboards. For cost-accounting, light and other fixed utility costs can be charged; but the lights will probably burn anyway, regardless of whether pallets are repaired in a location or not. The same applies to heat and other fixed utility costs, which will not change whether pallets are repaired or not.

The following standards for repairing pallets were developed in this study:

1. Productivity: one pallet repaired every 7 minutes.
2. Material: up to three deckboards—18 nails.
3. Cost of nails: about $2.75 per 1,000.
4. Cost of deckboards: $0.08 to $0.26 each, depending on quality, dimensions, champfering, etc.
5. Decision to repair: should be supervised by one person.
6. Location: centralized at one repair station — recommend maintenance department.
7. Flexibility: do not create new job classification.
8. Cost of repair: for labor, deckboards, and nails—up to $0.88 per pallet.
9. Contract cost for repair: $1.25 to $1.75, depending on geographical location.

As a guide to management for measuring the labor costs of handling a case of goods by the various handling methods, the following standards were developed. In working out these standards, we first established the variables that most effect the efficiency of unit loading.

PHILOSOPHY OF STANDARDS

After the variables were documented, the criteria that form the basis of present methods for measuring productivity were examined. These methods reflected the use of controls that were established before the advent of unit-load systems, and that were designed for piece handling. It was concluded that measuring productivity in tons per man-hour is of limited value when pieces are handled individually. However, even in piece handling other actions are performed by the employee besides handling products, and the time to accomplish these actions is included in the measure of tons or pieces handled per man-hour. While it is an accepted fact that the cubic volume and weight of the package also causes variations in productivity in piece handling, they are predictable, and therefore controllable.

In unit-load handling, tons or pieces handled per man-hour do not provide a meangingful measure of productivity of an employee. He performs the same task (driving a forklift truck) regardless of the size, shape, or weight or the unit load. Therefore a different measure of employee productivity is needed in unit-load handling. The most simple, predictable method of measuring unit-load handling is the number of unit loads that can be moved between two given points in a unit of time. Both weight and pieces per man-hour become irrelevant as factors influencing productivity.

The common denominator with which management can measure labor productivity and compare the efficiency of the different systems must be direct labor cost in cents per case handled or cents per unit of product handled. It is essential that the buyer know the profit per item sold in terms of cents per unit of product; and it is equally essential to know the labor cost of handling a case of the product.

Based on this reasoning, and evaluated in terms of the variables found to influence productivity, the following standards are proposed as a guide to management for measuring the labor cost of handling a case of goods, in a product group, for either floor-loaded or unitized systems of handling.

Standard industrial engineering techniques were used in the development of these standards. Each employee was identified with the shipment he unloaded — for the 2,706 shipments received. After this identification of each employee with each shipment, a performance range was established, based on productivity within groups where all conditions were similar—except the employees unloading.

OPERATING STANDARDS

In the majority of the food-distribution centers, the measurements of tons handled per man-hour and pieces handled per man-hour include extraneous actions necessary to complete the major task of unloading. Neither measurement is precise when related to actual productivity of handling the product. However, because the common practice is to employ these measurements within the food industry, they have been included in the standards provided. These extraneous actions, with average times to complete, are shown below and they should not be ignored in using the standards.

Floor-Loaded Rail Shipments

The average times required to complete these actions for a standard box car were found to be 33 minutes. The actions included:

Before unloading.—Break seal, open door, set dock plate, and remove dunnage.

After unloading.—Remove dock plate, close and lock door, put on seal, and gather up and dispose of dunnage.

For a standard box car with interior bars these actions required 61 minutes. The same before- and after-unloading actions are required as for a standard box car, but an additional 28 minutes are required for removing and replacing the bars.

The performance ratings established, based on number of pieces handled per man-hour, are:

Product group	*Performance Rating*			
	Poor	*Fair*	*Good*	*Excellent*
1	—110	111-135	136-150	150+
2	—195	196-240	241-260	260+
3	—200	201-246	247-265	265+
4	—245	246-300	301-325	325+
5	—175	176-215	216-235	235+

This range of performance reflects the curve of better methods used.

Example of use.—Paper products (group I). There are 750 cases in a standard box car. Company policy provides for an unpaid lunch hour and two paid coffee breaks of 15 minutes each. Starting time 7:30 a.m.; quitting time 3:00 p.m.; total work time 6 hours 30 minutes. Actual time required to unload car was 6 hours (chargeable 6 hours 30 minutes) for one man. Seven hundred and fifty cases divided by 6.5 hours equals 116 cases per man-hour (fair performance). The direct labor rates of $3 per hour divided by 116 cases per hour equals 2.5 cents direct labor cost per case handled.

Unitized Rail Shipments

Standards for unit-load handling by wooden pallets and slip sheets reflect the characteristics of the systems themselves. To illustrate this relationship, following is a comparison of the operation of the two systems:

Wooden pallets	*Slip sheets*
Approach, enter, transport.	Approach, pause, line up, enter or pull, transport, place on pallet.
System employed in receiving, storage, selecting, shipping.	System employed in receiving only.
Two unit loads may be handled as one load.	Each unit load is handled individually.
Load may be handled from four sides.	Load can be handled from one side only.
All types of hand or motorized trucks may be used.	Only motorized trucks with special attachment may be used.

The actions before and after the unloading of the product require less time in cars specially equipped for unit-load handling than in a standard box car.

For a DFB (damage-free bulkhead) car, these actions require 18 minutes. They include:

Before unloading.—Break seal, open door, set dock plate, unlatch pivot-type bulkhead door, and recess side fillers.

After unloading.—Pull out and set side fillers, replace exchange pallets or cardboard side fillers or other type unit-load equipment used with slip sheets, latch bulkhead door and remove dock plate, close door and put on seal, and dispose of dunnage if used.

It is more efficient tc have different employees unload the floor-loaded portions of unitized cars than to have the employee handling the unit loads do it.

Standards for unitized rail shipments are:

	Minutes per unit load	
	Single-deck	*Double-deck*
Wooden pallets	1.0	1.5*
Slip sheets	2.0	4.0**

*Top and bottom handled as one unit load.

**Top and bottom handled as separate loads—(2 minutes each).

Properly unitized shipments on slip sheets require only one man in the car (the equipment operator). However, an additional man is often needed to assist the operator. The above standards for unitized shipments on slip sheets do not provide for this additional man.

Example of use.—With wooden pallets (WP)—1,850 cases in car on 32 pallets—double-decked equals 16 lifts. With slip sheets (SS)—1,850 cases in car on 32 slip sheets—double-decked equals 32 lifts.

	Minutes to handle unit loads per car	+	*Minutes to handle other action*	=	*Total minutes to unload car*	×	*Labor rate per man-hour*	=	*Total labor cost*	÷	*Number cases in car*	=	*Cents per case labor cost*
WP	24		18		42		$3.00		$2.10		1,850		0.13
SS	64		18		82		$3.00		$4.10		1,850		0.22

If this were a floor-loaded car and the standard for this product were 300 cases per hour, it would be expressed as follows:

1,850 ÷ 300 = 6.2 hours

6.2 × $3.00 = $18.60 ÷ 1,850 = 1.00 cent per case

Most cars containing unit loads on wooden pallets will have 44, 56, or 64 pallet loads in the car. This 32-pallet example was used for comparison purposes with the slip-sheet cars.

Floor-Loaded Truck Shipments

The performance ratings established, based on number of pieces handled per man-hour, are:

Product group	*Performance rating*			
	Poor	*Fair*	*Good*	*Excellent*
1	—130	131-160	161-175	175+
2	—200	201-250	251-280	280+
3	—230	231-280	281-305	305+
4	—255	256-300	301-340	340+
5	—180	181-220	221-240	240+

Unitized Truck Shipments

Wooden pallet	*Minutes per unit load*	
	Single-decked	*Double-decked*
Hand pallet jack	1.50	—
Electric pallet jack	1.25	—
Forklift truck	1.00	1.25

EFFICIENCY RATING OF SHIPPERS

While the different systems of receiving and handling products at food-distribution centers cause fluctuations in labor costs, poor loading practices of shippers will also have a substantial effect on these costs. By using the employee-productivity standards provided in this report, it is possible to rate the shippers and isolate those practices that adversely affect the handling efficiency of the distribution center. Figure 6 is an example of one shipper rated at 10 different distribution centers. Though fluctuations are caused by variations in handling practices between distribution centers, the consistent pattern of poor performance indicates a need for improvement by this shipper in his loading practices (fig. 6).

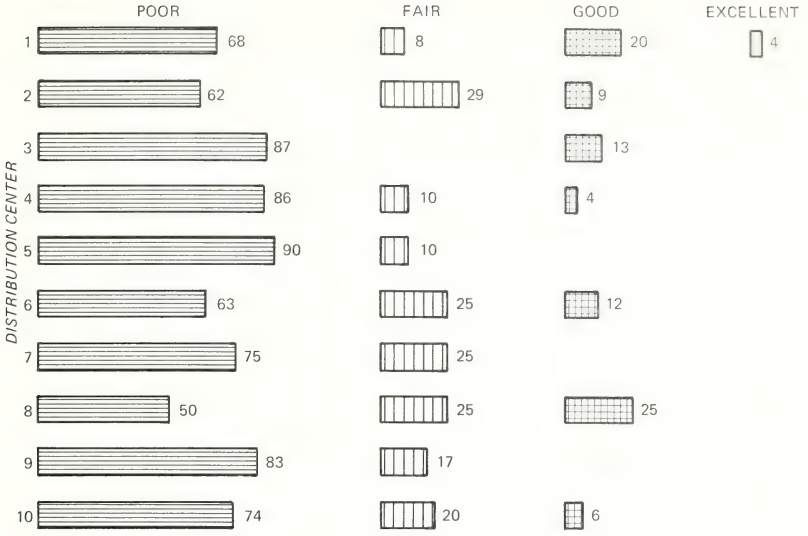

Figure 6.—How efficiently has the shipper prepared the shipment? These ratings of shipments from one shipper were based on productivity performance at 10 distribution centers. Values shown are percentages of total shipments to distribution center.

Summary & Conclusions

The concept of unit-load handling is applicable to the food industry. It can provide substantial benefits if companies entering such a program plan and schedule their entry carefully. In the planning, a company must recognize the limitations of the system and provide a framework that can be used under normal operating conditions by present personnel.

These conclusions are the result of (1) continuous work with manufacturers, carriers, receivers, and trade associations during the last 5 years in developing cost-reduction programs for the handling and physical distribution of food products; and (2) a detailed analysis of 2,706 shipments moving from 422 manufacturers to 10 major food-distribution centers.

Present methods used by most manufacturers and food-distribution centers in their shipping and receiving operations are

geared to piece handling. These systems and methods are not suited to the accelerated pace of modern materials handling.

The general impression in the industry that a compromise system of unitization is better than no system at all is erroneous. Many companies involved in unit-load programs profess to be employing the total concept approach, when in reality they concentrate only on the loading and unloading of products and ignore the full benefits that are possible at every cost center from the receiving dock of the manufacturer to the receiving dock of the retail store. The full benefits cannot be obtained unless the program follows the total concept approach.

Unit loading can produce substantial savings. They will vary between $14 and $19 per car under daily operating conditions depending upon the nature of the product, the ability of personnel, size and weight of cases, personality of the company, supervision ratio, and use of workaday standards to measure productivity. Savings as high as $50 per car have been attained in isolated instances—a measure of the gap between the best and the worst handling practices. The potential economies for the supplier, the carrier, and the receiver are sufficient to justify the investment each must make to weld together the parts of a unit-load program.

The wooden-pallet system is the only system that can be applied in a total concept from the handling of raw materials, through manufacture and distribution, to the retail store. Though some of the other handling systems can be shown to be more efficient within a given plant or in a given situation, none can be applied in a total concept throughout the entire system.

The wooden pallet-exchange program still faces substantial problems in uniformity of pallet quality and in instituting procedures to foster confidence in the program. One of the most difficult problems is policing the quality of the exchange pallets.

The greatest single value of a successful pallet-exchange program is the simplicity with which it can operate. The wooden pallet can be handled with conventional equipment that most companies of all sizes already have, such as hand pallet jacks,

electric pallet jacks, or forklift trucks. It requires no additional capital investment in special equipment.

Slip sheets were used most extensively in shipment of canned goods. The introduction of pull-pak has created several additional problems that must be corrected to gain the promised savings. It is a sound materials-handling principle but is difficult to apply in day-to-day operations.

The clamp truck system is used to a limited extent at distribution centers. Several problems connected with this system must be solved before it can be widely accepted. Experimental programs are continuing with this system for motor carrier transportation.

Paperwork at the manufacturer's plant and the distribution center has grown far too complicated and is a major cause of delay in shipping and receiving unit loads. By realigning the flow from the point at which the purchase order is created, the order can be transmitted, processed, filled, shipped, received, and paid for with 60 percent less paperwork than is now being used.

Pallet patterns also affect handling efficiency at the manufacturer's level, during shipment, and at the distribution center. The size of the cases and the arrangement of them to provide a stable pallet load requires considerable thought and detailed planning.

A new era in overs, shorts, and damage has evolved since the birth of the unit-load concept. Properly planned unit loads reduce damage to products by 62 to 73 percent: improperly planned unit loads increase the damage to products 23 to 58 percent beyond that experienced with the same product floor-loaded. It is a paradox that the same system, which provides the means of reducing claims, will also increase claims when improperly applied.

A National Pallet-Exchange Program

Since the idea of a national wooden pallet-exchange program was first proposed about 7 years ago, positive progress has been made in spite of a multitude of problems. Some of the more significant accomplishments to date are:

- A specification for a standard size and quality of pallet has been accepted by leading associations of the food industry.
- Thirty-nine companies have initiated and are operating exchange programs with their customers.
- Carriers, both rail and motor, have provided incentives in their tariffs for unit loads on wooden pallets.
- Rail carriers have invested millions of dollars in special equipment designed specifically for unit-load systems in the food industry.
- Trade associations have held hundreds of committee meetings and seminars on the subject of unit-load handling.
- Government personnel have spent thousands of man-hours developing information on the subject.

Such accomplishments demonstrate real progress, and bring the goals of a national program closer to reality. Industry has brought this program to the point where full-time personnel ought to be devoted to organizing and operating a national program to realize its full potential.

A master working plan is needed to analyze the wealth of information available and to prepare a national program acceptable to, and for the benefit of, all participants. This master working plan should provide for:

- Operating rules, systems, and procedures for all participants, in clear language.
- Establishment of the responsibilities of participants in the program.

- Inspection service on the quality of pallets being exchanged in the program.
- Research studies and test programs on new methods, for the benefit of all participants.
- Training programs to reduce damage both to product and to carrier equipment.
- Accumulation and analysis of statistics that will provide trends as to costs and savings in all types of unit-load programs.
- Guidance and assistance to companies when installing an exchange program.
- Preparation of a monthly or bi-monthly bulletin for all members that would include: latest news on unit-load handling, and results of research and test programs; a "Question Box" and "Gripe" section which would not identify the writers, but which would bring into focus the problems of the industry; and articles on meetings, events, etc., that discuss the subject of unit-load handling.

In addition to laying the groundwork for an orderly implementation of a national wooden pallet-exchange program, the master working plan should also provide practical answers to questions that have plagued the members of industry for the last 7 years every time the concept of such a program has been discussed. Some of these questions are:

Why must an exchange program start with the customer and work back?

Are administrative, bookkeeping and record-keeping costs necessary?

Should there be a legal and binding contract between the partipants?

Who should be responsible for the actions of the manufacturer, the carrier, and the customer in the program?

Why must the program operate with common ownership of pallets rather than individual ownership?

Which activities of the manufacturer, the carrier, and the receiver benefit from unit-load handling? How can they benefit?

Why do they benefit?

What are the limitations in a pallet-exchange program?

Why is agreement needed in a step-by-step approach as the program grows?

Why are the numbers of layers important for some products and unimportant for others?

Why are productivity standards needed for specific product groups rather than an average for all product groups?

Who benefits most in unit-load handling—the manufacturer, the carrier, or the customer?

What should be done to the shipper or customer who cheats on pallet quality?

What conditions now existing at manufacturer, carrier, and receiver levels cause the most damage to product?

How much money does a rail carrier invest in the specially equipped 50-foot 6-inch DFB car?—the 60-foot car?

What is the weight of a conventional forklift truck — with two tines? With special attachments for push-pak? For pull-pak? For clamp truck?

How much does each of the above attachments cost? What is their total use?

Why is the 48 x 40-inch, 4-way, non-reversible, notched-stringer, flush-type pallet best for the exchange program?

What quality wooden pallet is best in an exchange program? What is the break-even point in quality?

Does the success of a national program depend on more than one type of pallet because of geographical differences?

Why must specifications for a pallet that will be used in an exchange program also cover specifications for materials used in repairing these pallets?

How can introduction of inferior pallets into the exchange program be avoided?

Who should provide the pallets for the program?

Who should repair the pallets in the program?

How many pallets are necessary for each participant in an exchange program?

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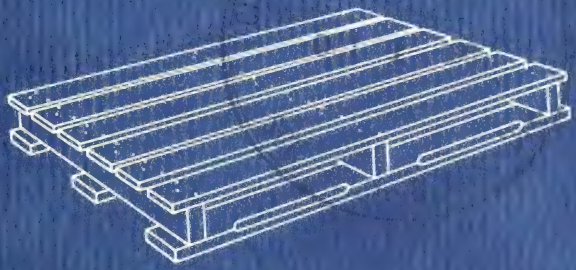
The Department of Defense Market for WOODEN PALLETS: 1966



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The Department of Defense Market for WOODEN PALLETS: 1966

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AN ADDENDUM

FOR THE BENEFIT of pallet suppliers and Department of Defense materials-handling personnel, we have prepared this paper to bring the information in THE DEPARTMENT OF DEFENSE MARKET FOR WOODEN PALLETS: 1965[1] up to date for 1966. A study of the market has been made to show what kinds of pallets the Department of Defense (DOD) uses, how DOD purchases pallets, and what the range of pallet prices is. Unless otherwise noted, all information relates to conditions in 1966 and 1967.

QUALITY AND QUANTITY REQUIREMENTS

The list of Department of Defense (DOD) standard pallets includes 24 different pallets. Each one is designated by a Federal Item Identification Number (FIIN). Four of the pallets were not on the list in the original report (see the last four pallets in table 1).[2] The Defense General Supply Center (DGSC), at Richmond, Va., added three of the FIIN's because seasoned hardwood lumber was scarce in 1965 and early 1966.[1] DGSC has also recently waived moisture-content limits on an experimental basis (either by formal amendment or written permission) for stringers and posts of some of the pallets identified by the first FIIN's in table 1. The other FIIN (959-0743) describes a pallet that DOD previously purchased as a non-standard item.

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[1] Lucas, John T., and Walter B. Wallin. THE DEPARTMENT OF DEFENSE MARKET FOR WOODEN PALLETS: 1965. U. S. Forest Serv. Res. Paper NE-117. 42 pp. NE. Forest Exp. Sta., Upper Darby, Pa. 1968.

[2] All tables are in Appendix.

Of the 24 FIIN's, softwood pallets are designated by 6: hardwood-softwood combination pallets are designated by 2; and hardwood pallets are designated by 16. Nine of the above FIIN's designate knocked-down pallets (table 1).

DOD changed several pallet specifications in 1967. Specifications MIL-P-15011E and MIL-P-26966C were combined to form the new specification MIL-P-15011F. And purchase description USA TRECOM-PD-14 was replaced by specification MIL-P-43465. These modifications are not shown in table 1 because pallets bought in 1966 conformed to the original specifications and FIINs.

In 1966, 20 of the 24 standard pallets, which are described by seven different specifications (table 1), were purchased by DGSC (table 2). Four of the pallets (FIIN's 063-9075, 926-1047, 599-5326, and 141-7261) constituted 82.5 percent of the nearly 3 million wooden pallets purchased by DGSC in 1966. Thirty-five percent of the wooden pallets bought by DGSC were softwood units, and 11 percent were knocked-down units (table 2).

Of the four pallets that were not purchased, three very likely will be eliminated from the standard list—FIIN's 955-9632 and 956-2950—because DGSC finds it increasingly difficult to get firms to bid on preservative-treated pallets and FIIN 141-7262 because DOD no longer has any use for it. Although no purchases were recorded for FIIN 926-3748 (a softwood pallet), the same pallet made of hardwood was very likely purchased under FIIN 222-1053 in 1966.

DOD has not decided whether one primary kind of pallet will be adopted. It appears very likely that both a post pallet (FIIN 141-7261) and a notched-stringer pallet (FIIN 599-5326) will be designated as primary—the post pallet for overseas shipments and a choice of the post or notched-stringer pallet for domestic shipments. In 1966, 15 percent of the wooden pallets purchased by DGSC were post pallets and 85 percent were stringer pallets, principally with notched-stringers (table 2). Both of the proposed primary pallets are wing pallets. Sixteen of the 24 FIIN's designate wing pallets, and 94.4 percent of all pallets purchased by DGSC in 1966 were wing pallets (table 2).

PROCUREMENT AND CONTRACT PERFORMANCE

In 1966, most pallets were purchased by negotiation because requirements could not be met through normal bidding procedures. As DOD pallet demand slackened in 1967, competitive bidding became the primary means of purchasing pallets.

In 1965 and 1966, DGSC entered into definitive contracts (fixed quantity and fixed price) and requirements contracts (open-end quantity and fixed price).[1] In 1967, an additional kind of contract—indefinite quantity contract (indefinite quantity and fixed price) — was adopted. It specifies a guaranteed minimum quantity of pallets DOD is obligated to order at a fixed price during the specified life of the contract. It also specifies a maximum quantity that may, at DOD's option, be ordered during the life of the contract.

As of January 1967, the DGSC wooden pallet mailing lists included 284 firms. In 1966, DGSC bought wooden pallets from 73 different firms (table 3). Twelve firms supplied 51.0 percent of the pallets, and the largest supplier accounted for 5.8 percent.

California was the leading supplier state with 17 firms selling wooden pallets to DGSC. Mississippi, North Carolina, Virginia, and Ohio were the next leading states in that order in terms of number of firms supplying pallets (table 3).

Almost two-thirds of all wooden pallets sold to DGSC in 1966 were produced in four states. California supplied 26.3 percent; Arkansas supplied 14.0 percent; North Carolina supplied 12.6 percent; and Virginia supplied 9.6 percent (table 3).

All the DGSC wooden pallet purchases in 1966 were from small business firms (500 or fewer employees). One-fourth of the purchases were from firms in labor-surplus areas, and three-fourths were from firms in non-labor-surplus areas.

In 1966 forty-five percent of the wooden pallets were purchased f.o.b. origin, and 55 percent were purchased f.o.b. destination (table 4). Two changes were made in mid-1967. The terms f.o.b. origin and f.o.b. designation were replaced respectively by f.o.b. origin (Government bills of lading) and f.o.b.

origin (freight prepaid to destination by contractor). Also in 1967, invitations for bids and requests for proposals for oversea shipments allowed contractors to specify ports in their immediate vicinity for loading if the port had the necessary facilities for handling the shipment.

The method of shipment for different kinds of pallets in 1966 was like that in 1965.[1] DGSC purchased 86.2 percent of the knocked-down pallets, 40.0 percent of the assembled pallets, 16.8 percent of the softwood pallets, and 60.1 percent of the hardwood pallets f.o.b. origin (table 4).

Average prices paid for wooden pallets bought f.o.b. origin in 1966 ranged from 2.1 to 106.4 percent higher than the prices paid in 1965 (table 5). As anticipated, these increases were higher than for any other comparable period since 1962 because pallet demand and lumber scarcities had increased sharply. DOD officials expected average prices to be lower for many of the pallets in 1967. The average prices for the two softwood pallets that were purchased f.o.b. origin in both 1965 and 1966 increased 19.8 and 30.1 percent during the 2 years. In contrast, 1965-66 price increases were greater than 32 percent for all but one of the hardwood pallets purchased f.o.b. origin (table 5).

The percentage range from the low to high f.o.b. origin price (based on the low price) paid for a specific pallet in 1966 varied from a low of 10.3 percent to a high of 171.8 percent (table 6). In 1965 the greatest range was 78 percent. Ranges in 1966 were above 90 percent for 6 of the 18 pallets bought f.o.b. origin. As in 1965, there appears to be no significant relationship between order size and price.

Wooden pallet prices increased during the first three quarters of 1966 and generally decreased in the fourth quarter (table 7). This decrease is probably due to a series of factors: (1) lumber became more readily available to pallet producers; (2) DOD demand for pallets slackened because a change in policy called for goods that formerly were shipped on pallets to be shipped in plywood containers; and (3) new firms entered the market, creating greater competition among pallet suppliers.

In 1965, prices were generally lower for pallets supplied from two regions; but in 1966 prices for pallets supplied from the

Figure 1. — DGSC distribution areas in the United States.

same regions were not consistently lower than prices for the same pallets supplied from other regions (table 8 and fig. 1).

The time required by DOD to pay for pallets has been decreased because: (1) payments are handled by the numerous Defense Contract Administration Services Region offices rather than by one central location; and (2) f.o.b. destination shipments have been replaced by f.o.b. origin (freight prepaid to destination by contractor) shipments, allowing the contractor to be paid as soon as the administrative contracting officer receives evidence that the pallets have been placed in a common carrier rather than when pallets arrive at the destination point.

WHERE AND WHEN THE PALLETS ARE NEEDED[1]

In 1966, DGSC received requisitions for 3,479,640 wooden pallets from DOD and purchased 2,987,515.

The shipment destinations for pallets were not recorded by state in 1966 as they were in 1965. However, there is no reason to suspect any appreciable change from 1965. California and Virginia very likely were still the leading states in terms of receipt of pallet shipments because a large number of overseas shipments originate from ports in these states.

Nearly 70 percent of the wooden pallets bought by DGSC in 1966 went to the armed forces. Most of the wooden pallets went to the U. S. Army (41.3 percent), followed by the U. S. Navy (25.3 percent), the U. S. Marine Corps (1.9 percent), and the U. S. Air Force (1.3 percent). Thirty percent of the pallets (table 9) went to other recipients — the Coast Guard, General Services Administration, and the Military Assistance Program.

More pallets were required in July (14.5 percent) than in any other month in 1966. And except for July and October, monthly pallet demand was lower in the second half of 1966 than in the first half. As in 1965, more pallets were required in June (10.2 percent) than in any of the other first 6 months. Demand was low in November and December because more plywood containers were used to ship goods that formerly were shipped on pallets (table 10).

Installations in the Tracy region (fig. 1) required 50.8 percent of the pallets. Installations in the Richmond region required 22.9 percent (table 11). As in 1965, most of the softwood and knocked-down pallets were required by the Tracy and Richmond regions (80.3 percent of the softwood pallets and 86.1 percent of the knocked-down pallets) (table 11).

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Table 1.—*Standard DOD wooden pallets*

Federal Item Identification Number (FIIN)[1]	Specification or purchase description number	Assembled (A) or knocked-down (Kd)[2]	Type of lumber[3]	Dimensions (inches)	Number and type of deck supports	Entry	Sides
063-9075*	NN-P-71b	A	Softwood	40 x 48	3 stringers	2-way	Double wing
063-9076	NN-P-71b	A	Hardwood	40 x 48	3 stringers	2-way	Double wing
141-7237	MIL-P-26966C	A	Softwood	40 x 48	9 posts	4-way	Flush
141-7261*	MIL-P-15011E	A	Hardwood	40 x 48	9 posts	4-way	Double wing
141-7262	MIL-P-4894	A	Softwood	40 x 48	3 stringers	2-way	Flush
202-2217	MIL-P-15943B	A	Hardwood	48 x 72	3 stringers	2-way	Double wing
222-1044	NN-P-71b	A	Hardwood	48 x 60	5 stringers	2-way	Flush
222-1046	NN-P-71b	A	Hardwood	32 x 40	3 stringers	2-way	Flush
222-1048	NN-P-71b	Kd	Hardwood	32 x 40	3 stringers	2-way	Flush
222-1051	NN-P-71b	Kd	Hardwood	48 x 60	5 stringers	2-way	Flush
222-1053	MIL-P-15943B	Kd	Hardwood	48 x 72	3 stringers	2-way	Double wing
223-6529	MIL-P-15011E	Kd	Hardwood	40 x 48	9 posts	4-way	Double wing
291-8717	NN-P-71b	Kd	Hardwood	40 x 48	3 stringers	2-way	Flush
542-3294	MIL-P-22562	A	Hardwood	32 x 40	3 notched stringers	Partial 4-way	Double wing

555-0458	NN-P-71b	A	Hardwood	40 x 48	3 stringers	2-way	Flush
599-5326*	MIL-P-3938B	A	Hardwood	40 x 48	4 notched stringers	Partial 4-way	Double wing
892-4394	USA TRECOM-PD-14	Kd	Softwood	572x232¼	3 notched stringers	Partial 4-way	Double wing
892-4395	USA TRECOM-PD-14	Kd	Softwood	44 x 31⅜	3 notched stringers	Partial 4-way	Double wing
955-9632	USA MO(AVISCOM) PD-367A	A	Hardwood and Softwood	48 x 72	3 stringers	2-way	Double wing
956-2950	USA MO(AVISCOM) PD-367A	Kd	Hardwood and Softwood	48 x 72	3 stringers	2-way	Double wing
926-1046	MIL-P-15011E	A	Hardwood	40 x 48	9 posts	4-way	Double wing
926-1047*	MIL-P-3938B	A	Hardwood	40 x 48	4 notched stringers	Partial 4-way	Double wing
926-3748	MIL-P-15943B	Kd	Softwood	48 x 72	3 stringers	2-way	Double wing
959-0743	NN-P-71b	A	Hardwood	48 x 48	3 stringers	2-way	Double wing

[1] The four kinds of pallets designated by an asterisk (*) beside the FIIN's constituted 82 percent of the number of pallets purchased in 1966.

[2] The knocked-down category refers to parts for pallets that are packaged for shipment to a DOD installation, generally overseas, where fabrication takes place. All but three are shipped in bundles containing parts for 20 pallets; FIIN's 222-1053, 956-2950, and 926-3748 require parts bundled for one pallet only.

[3] Some DOD specifications and purchase descriptions allow only certain species for pallet construction — in several instances, low-density broadleaf species are classified as "softwoods."

Table 2.—*Wooden pallets purchased by DGSC in 1966, by Federal Item Identification Number*

(Numbers in boldface indicate knocked-down pallets)

Federal Item Identification Number (FIIN)[1]	Number of pallets	Percent
†063-9075	875,730	29.31
926-1047	656,485	21.98
599-5326	596,037	19.95
141-7261	337,522	11.30
†892-4394	141,986	4.75
291-8717	66,900	2.24
926-1046	52,315	1.75
223-6529	49,080	1.64
202-2217	34,108	1.14
959-0743	28,634	.96
222-1051	27,620	.93
555-0458	24,691	.83
542-3294	18,879	.63
222-1044	17,209	.58
†892-4395	15,820	.53
222-1046	13,483	.45
222-1053	11,365	.38
†141-7237	10,273	.34
222-1048	6,680	.22
063-9076	2,700	.09
All pallets	2,987,517	100.00

[1] See table 1 for descriptions of the pallets.
† Softwood pallets.

Table 3.—*Wooden pallets supplied in 1966, by States and firms*

State	Number of firms	Number of pallets	Percent of pallets
California	17	784,555	26.26
Arkansas	3	417,173	13.97
North Carolina	6	375,593	12.57
Virginia	5	286,359	9.59
Mississippi	8	217,947	7.30
Texas	4	149,390	5.00
Alabama	4	135,106	4.52
Colorado	2	117,313	3.93
Washington	4	94,132	3.15
New Jersey	2	89,568	3.00
Maryland	1	80,074	2.68
Ohio	5	54,151	1.81
Georgia	2	40,699	1.36
Pennsylvania	2	39,912	1.34
Oregon	1	38,041	1.27
Tennessee	2	28,504	.96
Iowa	1	18,000	.60
Illinois	1	12,000	.40
Utah	1	7,600	.25
Kentucky	1	1,000	.03
New York	1	400	.01
Total	73	2,987,517	100.00

Table 4.—*Wooden pallets purchased by DGSC in 1966, by type of shipment and Federal Item Identification Number*

(Numbers in boldface indicate knocked-down pallets)

Federal Item Identification Number (FIIN)[1]	F.o.b. origin		F.o.b. destination		Total pallets purchased
	Number	*Percent*	*Number*	*Percent*	*Number*
†063-9075	50,150	5.73	825,580	94.27	875,730
926-1047	335,735	51.14	320,750	48.86	656,485
599-5326	315,392	52.91	280,645	47.09	596,037
141-7261	251,438	74.50	86,084	25.50	337,522
†**892-4394**	107,330	75.59	34,656	24.41	141,986
291-8717	64,600	96.56	2,300	3.44	66,900
926-1046	47,315	90.44	5,000	9.56	52,315
223-6529	49,080	100.00	—	—	49,080
202-2217	29,339	86.02	4,769	13.98	34,108
959-0743	6,000	20.95	22,634	79.05	28,634
222-1051	27,620	100.00	—	—	27,620
555-0458	10,100	40.91	14,591	59.09	24,691
542-3294	9,293	49.22	9,586	50.78	18,879
222-1044	—	—	17,209	100.00	17,209
†**892-4395**	10,040	63.46	5,780	36.54	15,820
222-1046	4,900	36.34	8,583	63.66	13,483
222-1053	11,365	100.00	—	—	11,365
†141-7237	8,300	80.79	1,973	19.21	10,273
222-1048	5,260	78.74	1,420	21.26	6,680
063-9076	—	—	2,700	100.00	2,700
All FIIN's	1,343,257	44.96	1,644,260	55.04	2,987,517

[1] See table 1 for descriptions of the pallets.
† Softwood pallets.

Table 5.—*Average f.o.b. origin wooden pallet prices, 1965-66, by pallet Federal Item Identification Number*

(Numbers in boldface indicate knocked-down pallets)

Federal Item Identification Number (FIIN)[1]	1965	1966	Change in price 1965-1966
			Percent
†063-9075	$ 2.06	$ 2.68	+30.1
063-9076	(2)	(3)	—
†141-7237	(3)	3.58	—
141-7261	3.23	4.51	+34.3
†141-7262	(2)	(2)	—
202-2217	9.86	16.87	+71.1
222-1044	(2)	(3)	—
222-1046	1.88	1.92	+2.1
222-1048	2.20	3.37	+53.2
222-1051	4.61	6.86	+48.8
222-1053	12.25	25.30	+106.5
223-6529	4.58	6.06	+32.3
291-8717	2.55	4.97	+94.9
542-3294	(2)	2.88	—
555-0458	2.55	3.71	+45.5
599-5326	3.16	4.61	+45.9
†**892-4394**	(3)	3.54	—
†**892-4395**	2.52	3.02	+19.8
955-9632	(2)	(2)	—
956-2950	(2)	(2)	—
926-1046	(2)	5.15	—
926-1047	(2)	4.31	—
†**926-3748**	(2)	(2)	—
959-0743	(2)	4.00	—

[1] See table 1 for descriptions of the pallets.
[2] No pallets were purchased.
[3] All pallets were purchased f.o.b. destination.
† Softwood pallets.

Table 6.—*F.o.b. origin wooden pallet prices, 1966, by pallet Federal Item Identification Number*

(Numbers in boldface indicate knocked-down pallets)

Federal Item Identification Number (FIIN)[1]	Average price	Price range	Price range
			Percent
†063-9075	$ 2.68	$ 1.68- 3.76	123.8
†141-7237	3.58	2.75- 3.89	41.5
141-7261	4.51	3.02- 6.10	102.0
202-2217	16.87	12.70-21.80	71.7
222-1046	1.92	1.85- 2.04	10.3
222-1048	3.37	3.25- 3.80	16.9
222-1051	6.86	6.23- 7.10	14.0
222-1053	25.30	24.81-28.89	16.4
223-6529	6.06	4.64- 6.49	39.9
291-8717	4.97	2.45- 6.66	171.8
542-3294	2.88	2.88- 3.25	12.8
555-0458	3.71	3.33- 4.41	32.4
599-5326	4.61	2.73- 6.00	119.8
†892-4394	3.54	2.79- 5.40	93.5
†892-4395	3.02	2.06- 4.00	94.2
926-1046	5.15	4.65- 5.50	18.3
926-1047	4.31	4.05- 4.55	12.3
959-0743	4.00	3.58- 4.75	32.7

[1] See table 1 for descriptions of the pallets.
† Softwood pallets.

Table 7.—*Average f.o.b. origin wooden pallet prices, 1966, by quarter of the year and pallet Federal Item Identification Number*

(Numbers in boldface indicate knocked-down pallets)

Federal Item Identification Number (FIIN)[1]	1 January-March	2 April-June	3 July-September	4 October-December	Average
†063-9075	$1.88	$ 3.28	$ 3.45	—	$ 2.68
†141-7237	—	3.72	—	$ 3.58	3.58
141-7261	4.16	4.68	5.03	—	4.51
202-2217	—	16.53	17.22	20.29	16.87
222-1046	1.93	1.85	1.93	—	1.92
222-1048	3.50	—	3.80	3.30	3.37
222-1051	6.23	7.00	7.10	—	6.86
222-1053	—	—	37.27	24.81	25.30
223-6529	6.47	4.64	6.48	6.56	6.06
291-8717	3.22	3.77	5.78	4.36	4.97
542-3294	3.25	—	—	2.88	2.88
555-0458	3.33	3.62	4.20	—	3.71
599-5326	3.60	4.42	5.61	4.29	4.61
†**892-4394**	2.89	3.14	3.32	3.98	3.54
†**892-4395**	2.06	—	2.96	3.30	3.02
926-1046	—	—	5.37	5.12	5.15
926-1047	—	—	4.28	4.35	4.31
959-0743	—	3.82	—	4.02	4.00

[1] See table 1 for descriptions of the pallets.
† Softwood pallets.

Table 8.—*Average f.o.b. origin wooden pallet prices, 1966, by geographical region of the suppliers and pallet Federal Item Identification Number*

(Numbers in boldface indicate knocked-down pallets)

Federal Item Identification Number (FIIN)[1]	Region[2]						Average
	Richmond	Atlanta	Memphis	Columbus	Ogden	Tracy	
†063-9075	$ 3.68	—	$ 3.42	—	—	$ 2.19	$ 2.68
†141-7237	3.08	—	—	—	—	3.84	3.58
141-7261	4.30	—	4.50	$ 5.37	—	—	4.51
202-2217	16.89	—	21.80	12.70	—	—	16.87
222-1046	2.04	—	1.88	—	—	—	1.92
222-1048	3.34	—	—	—	—	3.75	3.37
222-1051	7.04	$ 6.23	—	—	—	—	6.86
222-1053	24.81	—	—	—	—	28.89	25.30
223-6529	5.97	—	4.64	—	—	6.48	6.06
291-8717	4.89	3.50	3.85	—	—	5.58	4.97
542-3294	2.88	3.25	—	—	—	—	2.88
555-0458	3.75	—	3.75	3.64	—	—	3.71
599-5326	4.70	4.60	4.49	4.41	—	—	4.61
†**892-4394**	4.16	—	—	—	—	3.52	3.54
†**892-4395**	4.00	—	—	—	—	2.97	3.02
926-1046	5.30	5.50	5.02	5.44	—	—	5.15
926-1047	4.47	—	4.29	—	—	—	4.31
959-0743	4.01	4.00	—	—	—	—	4.00

[1] See table 1 for descriptions of the pallets.

[2] See figure 1 for regional boundaries.

† Softwood pallets.

Table 9.—*Wooden pallet demand in 1966, by service branch and pallet Federal Item Identification Number*

(Numbers in boldface indicate knocked-down pallets)

Federal Item Identification Number (FIIN)[1]	Service branch						Percent
	Army	Navy	Air Force	Marine Corps	Other[2]	Total	
†063-9075	132,900	392,043	6,393	18,153	427,130	976,619	28.07
063-9076	100	100	—	—	—	200	—
†141-7237	—	—	17,667	—	—	17,667	.51
141-7261	302,548	111,058	16,498	4,000	337,135	771,239	22.17
202-2217	37,031	950	875	—	—	38,856	1.12
222-1044	15,734	—	—	—	16,800	32,534	.93
222-1046	22,006	—	630	—	—	22,636	.65
222-1048	8,520	—	—	—	—	8,520	.24
222-1051	17,520	—	—	—	—	17,520	.50
222-1053	33,199	10	336	—	—	33,545[3]	.96[3]
223-6529	192,620	—	—	—	—	192,620	5.54
291-8717	83,760	—	540	—	—	84,300	2.43
542-3294	—	597	3,499	15,842	—	19,938	.58
555-0458	138,268	—	—	—	—	138,268	3.97
599-5326	229,774	298,095	60	26,673	227,458	782,060	22.48
†**892-4394**	169,960	—	—	—	3,040	173,000	4.97
†**892-4395**	15,760	—	—	—	3,820	19,580	.56
955-9632	3,000	—	—	—	—	3,000	.09
956-2950	40	—	—	—	—	40	—
926-1046	21,000	28,778	—	—	—	49,778	1.43
926-1047	15,000	48,640	—	—	33,900	97,540	2.80
Total	1,438,740	880,271	46,498	64,668	1,049,283	3,479,460[4]	—
Percent	41.32	25.31	1.34	1.87	30.16	100.00	—

[1] See table 1 for descriptions of the pallets.
[2] Coast Guard, Military Assistance Program, GSA, and others.
[3] Twenty-seven thousand of the pallets recorded under FIIN 222-1053 by DGSC actually conformed to FIIN 926-3748.
[4] Does not include 16,066 pallets conforming to FIIN 959-0743 that were demanded in 1966.
† Softwood pallets.

Table 10.—*Wooden pallet demand in 1966, by month and pallet Federal Item Identification Number*

(Numbers in boldface indicate knocked-down pallets)

Federal Item Identification Number (FIIN)[1]	January	February	March	April	May	June	July	August	September	October	November	December	Total	Percent
†063-9075	153,392	111,770	94,750	20,659	193,650	145,819	123,140	14,934	4,529	113,414	544	18	976,619	28.07
063-9076	—	—	100	—	—	100	—	—	—	—	—	—	200	—
†141-7237	50	—	—	500	1,010	3,200	702	1,080	400	3,125	—	7,600	17,667	.51
141-7261	17,800	64,553	78,698	89,795	42,076	88,712	220,431	66,271	47,465	25,243	27,600	2,595	771,239	22.17
202-2217	—	6,900	—	2,531	508	15,020	423	8,872	1,100	1,002	2,500	—	38,856	.66
222-1044	450	1,255	—	1,511	4,050	1,510	15,555	1,623	—	700	1,799	4,081	32,534	1.11
222-1046	725	2,550	1,804	1,245	3,074	1,380	1,300	2,385	2,270	3,759	700	1,444	22,636	.94
222-1048	300	—	—	500	—	600	2,300	2,260	—	460	1,700	400	8,520	.24
222-1051	6,000	—	—	—	4,680	—	—	4,600	80	1,660	500	—	17,520	.49
222-1053	101	46	—	36	2,735	8	11,443	18,126	—	250	—	800	33,545[2]	.96[2]
223-6529	10,000	100	100	—	1,060	8,200	1,540	29,260	1,600	140,360	—	400	192,620	5.54
291-8717	600	800	400	6,760	—	—	2,500	55,980	1,040	3,440	10,780	2,000	84,300	2.42
542-3294	60	—	—	—	3,599	2,793	2,521	10,308	200	320	37	100	19,938	.57
555-0458	2,000	40	3,710	2,075	4,650	1,725	8,000	5,600	96,700	7,866	2,496	3,406	138,268	3.98
599-5326	74,960	115,613	157,940	77,003	58,317	66,632	47,089	47,824	49,760	19,176	19,162	48,584	782,060	22.47
†**892-4394**	1,720	5,480	1,760	2,200	6,460	16,760	60,480	29,700	13,840	12,900	12,920	8,780	173,000	4.97
†**892-4395**	60	2,500	980	40	1,500	640	6,480	3,700	1,680	700	900	400	19,580	.57
955-9632	—	—	3,000	—	—	—	—	—	—	—	—	—	3,000	.09
956-2950	—	—	—	—	—	40	—	—	—	—	—	—	40	—
926-1046	—	—	—	—	—	—	—	—	—	—	2,371	47,407	49,778	1.43
926-1047	—	—	—	—	—	—	—	—	—	25,400	51,340	20,800	97,540	2.81
Total	268,218	311,607	343,242	204,855	327,369	353,139	503,904	302,523	220,664	359,775	135,349	148,815	3,479,460[3]	—
Percent	7.70	8.95	9.86	5.87	9.41	10.15	14.50	8.70	6.35	10.35	3.89	4.27	100.00	—

[1] See table 1 for descriptions of the pallets.
[2] Twenty-seven thousand of the pallets recorded under FIIN 222-1053 by DGSC actually conformed to FIIN 926-3748.
[3] Does not include 16,066 pallets conforming to FIIN 959-0743 that were demanded in 1966.
† Softwood pallets.

Table 11.—*Wooden pallet demand in 1966, by location and pallet Federal Item Identification Number*

(Numbers in boldface indicate knocked-down pallets)

Federal Item Identification Number (FIIN)[1]	Location[2]									
	Atlanta[3]	Norfolk[4]	Oakland[5]	Tracy[6]	Columbus[7]	Memphis[8]	Richmond[9]	Ogden[10]	Total	Percent
†063-9075	5,062	95,137	274,374	436,754	1,500	618	15,044	148,130	976,619	28.10
063-9076	—	—	—	—	100	—	100	—	200	.02
†141-7237	3,350	—	—	11,552	635	1,800	—	430	17,667	.52
141-7261	49,505	27,815	33,080	289,260	80,738	110,201	107,676	72,964	771,239	22.18
202-2217	180	—	—	14,242	50	505	23,879	—	38,856	1.13
222-1044	4,200	—	—	3,373	—	20,724	1,637	2,600	32,534	.95
222-1046	345	—	—	1,882	400	13,990	5,569	450	22,636	.66
†**222-1048**	—	—	—	60	500	—	7,960	—	8,520	.25
†**222-1051**	—	—	—	—	—	—	17,520	—	17,520	.51
†**222-1053**	—	—	10	32,191	—	308	1,036	—	33,545[11]	.97[11]
†**223-6529**	100	—	—	186,920	—	200	5,400	—	192,620	5.54
†**291-8717**	—	—	—	73,200	100	600	10,400	—	84,300	2.43
542-3294	3,536	—	160	15,522	—	—	720	—	19,938	.58
555-0458	790	—	—	112,861	3,000	2,025	19,592	—	138,268	3.99
599-5326	91,246	5,400	7,620	224,766	55,414	70,900	271,958	54,756	782,060	22.48
†**892-4394**	7,560	—	—	35,240	10,200	45,180	74,820	—	173,000	4.78
†**892-4395**	3,520	—	—	—	8,760	1,640	10,660	—	19,580	.57
955-9632	—	—	—	—	—	1,640	—	—	3,000	.09
956-2950	—	—	—	40	—	—	—	—	40	—
926-1046	—	3,800	4,500	8,186	—	—	33,292	—	49,778	1.44
926-1047	11,340	—	—	—	5,500	26,800	53,900	—	97,540	2.81
Total	180,734	132,152	319,744	1,446,049	161,797	298,481	661,163	279,330	3,479,460[12]	—
Percent	6.00	3.81	9.20	41.61	4.68	8.62	19.05	8.03	100.00	—

[1] See table 1 for descriptions of the pallets.
[2] See figure 1 for the regional boundaries.
[3] Atlanta Army Depot, Forest Park, Ga.
[4] Naval Supply Center, Norfolk, Va.
[5] Naval Supply Center, Oakland, Calif.
[6] Defense Depot Tracy, Tracy, Calif.
[7] Defense Construction Supply Center, Columbus, Ohio.
[8] Defense Depot Memphis, Memphis, Tenn.
[9] Defense General Supply Center, Richmond, Va.
[10] Defense Depot Ogden, Ogden, Utas.
[11] Twenty-seven thousand of the pallets recorded under FIIN 222-1053 by DGSC actually conformed to FIIN 926-3748.
[12] Does not include 16,066 pallets conforming to FIIN 959-0718 that were demanded in 1966.

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by David R. Houston
and Harold G. Eno

Use of SOIL FUMIGANTS to Control Spread of *Fomes annosus*

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RICHARD D. LANE, DIRECTOR

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Use of SOIL FUMIGANTS to Control Spread of *Fomes annosus*

BACKGROUND

THE ROOT ROT caused by the fungus *Fomes annosus* is a serious threat to coniferous plantations throughout the North Temperate Zone. It is especially prevalent in plantations that have been thinned; and it commonly spreads through the roots from diseased trees to healthy trees.

In 1962-67 we conducted a series of experiments to provide preliminary information for testing the hypothesis: that a continuous band or zone of roots rendered unsuitable for invasion by *F. annosus* will prevent the underground spread of this fungus from diseased to healthy trees.

The initial introduction of *F. annosus* into a stand depends largely upon the occurrence of the first thinnings and consequently upon the age of the plantation. This is because fresh stump tissues offer especially suitable substrates for the germination of windborne basidiospores of *F. annosus*, and for the subsequent growth of the thallus *(Rishbeth 1950, 1951)*.

Many studies have been made of this initial establishment; and several control measures, designed to prevent invasion by the fungus into previously unaffected stands, have been developed. Materials have been found that, when placed on the stump surface at the time of felling, act in various ways to hinder development of the fungus. The most successful of these materials are those that encourage rapid colonization of the

stump and roots by competing saprophytic fungi. Urea *(Rishbeth 1959),* borax *(Driver 1963b),* and sodium nitrite *(Punter 1964)* are among the most promising of these materials. Promising results, too, have followed the direct inoculation of freshly cut stump tops with *Peniophora gigantea,* an aggressive saprophytic fungal competitor of *F. annosus (Garrett 1951 and Rishbeth 1961).* Thus, in spite of the need for more research on this phase of control, much has been learned; and quite effective and practical measures are now in actual use *(Driver 1963a).*

Once the fungus is established in the stand, however, control becomes infinitely more difficult. Spread of the fungus from infected stumps to adjacent standing trees is by means of root contacts. It is highly probable that every tree in a 30-to-40-year-old pine plantation, planted originally at a 6-x-6-foot

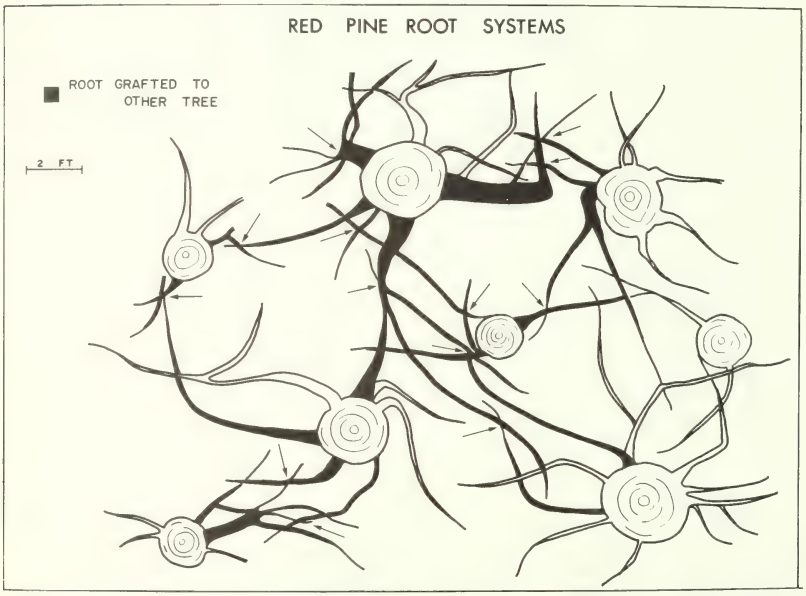

Figure 1. – The soil around the roots of these 30-year-old red pines was washed away with water to reveal the degree of root contact that occurred. Roots colored black are actually grafted to roots of other trees. *Fomes annosus* spreads from tree to tree underground by means of root contacts.

spacing and perhaps thinned once, is in root contact directly or indirectly with every other tree in the stand (fig. 1).

So potentially, once *F. annosus* has invaded the stand, all trees in the stand are subject to attack.

ELIMINATION OR REDUCTION OF ROOT CONTACTS

Root contacts could be reduced in one of two general ways. (1) They could be physically removed or severed by trenching, or interrupted by placing physical barriers below ground. Or (2) they could be treated in place by some means that would render them unsuitable for infection by *F. annosus*. *F. annosus* is not an aggressive saprophyte, and dead root tissues invaded first by other fungi are unlikely to be colonized subsequently by *F. annosus (Rishbeth 1951)*.

At the outset it appeared that soil fumigants might be utilized to kill roots in place. These materials are toxic to many plant roots and soil microorganisms, and have been used with success to control the underground spread of oak wilt *(Kuntz and Drake 1960)* and Dutch elm disease *(Himelick et al. 1963)*; and *F. annosus* was controlled temporarily in California by fumigating with carbon disulfide *(Bega 1962)*. So experiment 1 was conducted to determine the effects of fumigation on the healthy roots of several coniferous hosts of *F. annosus*.

Experiment 1

Effect of Soil Fumigants on Healthy Conifer Roots in Situ: Development of Techniques

Methods and Materials

A 25-year-old mixed plantation of red, Scots, and pitch pines, growing on a deep, fine, sandy outwash soil was used in this experiment. The stand was planted originally at a 6-x-6-foot

spacing and had not been thinned. Eighteen 6-foot-long plots were established in September 1962. Each plot was placed halfway along and perpendicular to a line connecting two adjacent trees. Different concentrations of two fumigants – methyl bromide[1] and SMDC (Vapam)[2] – were introduced to different depths in holes prepunched with a crowbar at 1-foot intervals along this line. The general scheme was that used by Kuntz and Drake *(1960)*. Methyl bromide at each of three concentrations (0.5, 1.0, and 2.0 pounds per 10 linear feet of plot) was introduced to each of nine plots (three plots at each concentration), by means of a MacLean rodent gun[3] to successive depths of 8, 16, 24, 24, 32, and 40 inches. A second hole at 24 inches was included to facilitate the timing of gas release from the 1-pound cans. The opening of each hole was closed with dirt after the fumigant was introduced. Dosages were regulated by timing the release of fumigant with a stopwatch.

Fifty, 100, or 200 ml./hole of SMDC stock solution diluted 1:10 were introduced to each of the other nine plots by a similar scheme except that only one 24-inch deep hole was used in each plot. After application, each hole opening was sealed with dirt.

The effect of fumigation on the soil microflora was studied. Four red pine plots (SMDC at concentrations of 50, 100, and 200 ml./hole; and methyl bromide at 2 pounds/10 linear feet) were sampled 2 weeks after fumigation. A soil auger was used to obtain samples from the 0-to-6-inch and 6-to-12-inch depths at distances of 6, 12, and 18 inches from the fumigation line opposite the 8-, 24-, and 40-inch-deep holes. Soil dilutions of 1:10,000, replicated three times, were plated into petri dishes containing peptone dextrose agar plus rose bengal and streptomycin *(Martin 1950; Johnson 1957)* in the manner described by Johnson et al. *(1959)*.

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[1]Dow Chemical Co., Midland, Mich. Mention of a particular product should not be taken as an endorsement by the Forest Service or the U. S. Department of Agriculture.

[2]Sodium *N*-methyldithiocarbamate; Stauffer Chemical Co., New York, N. Y.

[3]MacLean Equipment Co., Los Angeles, Calif.

Figure 2. – The pit was dug to permit measurement of the root injury produced by soil fumigant applied along the line between the two wooden stakes.

Approximately 1 month after fumigation the plots were excavated and the tree roots were examined for extent of injury (fig. 2).

Results

Figures 3 and 4 represent the general effects of methyl bromide on roots 1 month after fumigation and on the soil microflora 2 weeks after fumigation, respectively. Under the conditions of this test, the following general results and conclusions were obtained:

1. Red pine roots were killed readily by either SMDC or methyl bromide. Scots pine roots were slightly less affected and pitch pine roots were quite resistant.
2. Methyl bromide and SMDC at concentrations of 1 pound/10 linear feet and 200 ml./hole, respectively, applied to depths of 16 to 24 inches, killed the majority of red pine roots in a zone 2.5 to 3.5 feet wide on either side of the injection line.

Roots 3 to 6 inches in diameter were killed back to the root collar, but no injury occurred to the bole of the tree. Materials applied at the 8-inch depth were less effective than those applied at 16 or 24 inches both in the extent of horizontal root kill and in killing of surface roots. Fumigants applied at the 32-inch depth produced no added effect; and those applied 40 inches deep were not effective in killing roots near the surface.

3. The effects of fumigation upon the soil microflora at both the 0-to-6-inch and 6-to-12-inch levels were evident even 2 weeks after treatment. In general, the effects (decrease in colonies isolated) were greatest when the fumigants were applied to the 8-inch-deep holes and decreased as depth of application and horizontal distance from the line of injection increased, especially at the shallow depths. In the three SMDC plots examined, the effects increased with increasing concentrations of the fumigant.

Figure 3. – The condition of the roots in the upper 12 inches of soil 1 month after fumigation with methyl bromide at the rate of 1 pound per 10 linear feet of fumigation line.

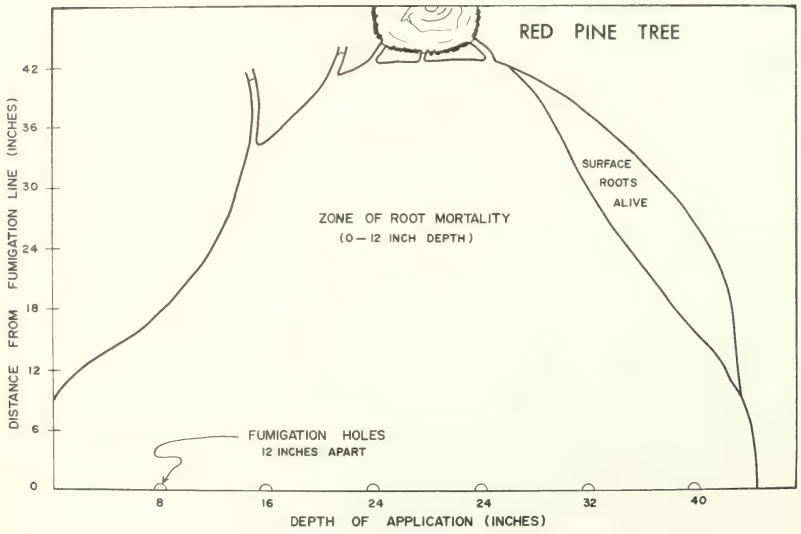
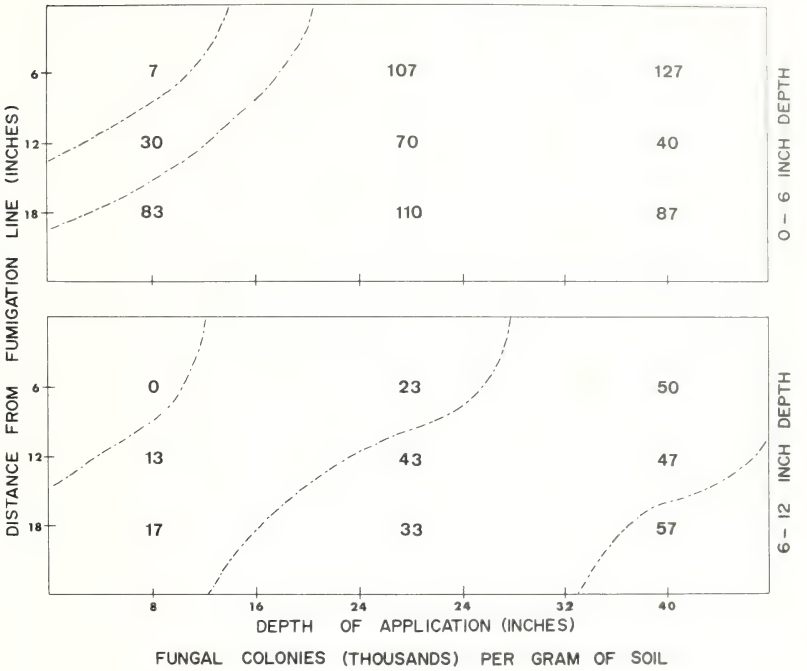


Figure 4. – Number (thousands) of fungal colonies per gram of soil isolated 2 weeks after fumigation with methyl bromide at 2 pounds per 10 linear feet of fumigation line. Each number is the average of three replicates.



Experiment 2

Influence of Soil Type and Season on Fumigant Effectiveness

Methods and Materials

Ten plots containing a total of 34 trees were established in June 1963 or in the spring and fall of 1964, using methyl bromide (1 pound/10, 8, or 7 linear feet of line) and SMDC (200 ml. of 1:10/hole) applied at 1-foot intervals along a line placed 4 feet from the trees, to a depth of 20 inches. Plots were located in a 35-year-old red pine plantation growing on a heavy sandy loam soil in northwestern Connecticut and in a 25-year-old stand growing on a light loamy sand in southeastern Connecticut. Both soils were heavier than that encountered in

experiment 1. Roots were excavated and examined for injury 3 to 12 months after treatment.

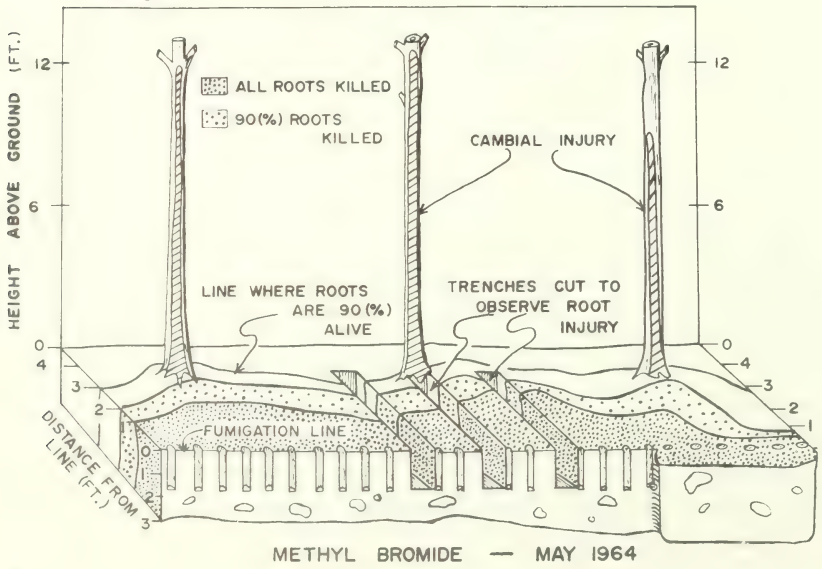
Results

Soil type. – Very little difference in extent of injury occurred that was attributable to differences in soil type, either in incidence (distance from line) or in the severity (percent root kill) of injury.

Season. – Differences, primarily in the extent of aboveground injury to the stems of trees adjacent to the fumigation line, occurred in plots treated at different times of the year. The cambium of trees on plots treated early in the season was killed in wide streaks that extended as high as 15 feet above ground (fig. 5). No injury above ground occurred on the trees in plots treated late in the season.

Methyl bromide versus SMDC. – Under the conditions of the tests in 1963 and 1964, SMDC did not give as effective or consistent results as methyl bromide did. The pattern of root mortality was erratic: often roots close to the fumigant line

Figure 5. – A representative example of the effects of methyl bromide applied to a depth of 20 inches at 1-foot intervals along a line 4 feet from red pine trees in the spring.



itself were injured but not killed. This apparent contradiction to the results of the 1962 test (experiment 1) may be due to the heavier soils encountered in the 1963 and 1964 experiments or to the restriction of injection to a single depth in 1963 and 1964. And, as noted above, the concentration of methyl bromide was increased in several trials in experiment 2 while that of SMDC was not.

STUDY II

EFFECT OF SOIL FUMIGANTS ON FOMES ANNOSUS IN INFECTED ROOTS OF RED PINE

Once it was determined that roots of red pine could be killed readily by soil fumigation, several questions arose that made it necessary to determine the effects of the fumigants upon root systems already colonized by *Fomes annosus:* (1) would the temporary elimination of competitive or antagonistic fungi near infected roots provide a more suitable environment for *F. annosus?* or (2) would the treatment encourage saprophytic fungi to rapidly colonize the sterilized roots? And (3) would the state of root deterioration influence the effectiveness of the fumigants? These questions were explored in experiments 3 to 6 summarized below.

Experiment 3

Effects of fumigants on F. annosus in variously-rotted root tissues

Methods and Materials

In June and July 1963 tests were carried out in a 25-year-old red pine stand in north-central Connecticut. The stand, growing on a sandy outwash soil, had been thinned once in 1956. Treatments were applied to thirteen plots, each of which contained one of the following:

1. The infected stump and roots of a tree cut in 1956.
2. The infected stump and roots of a tree killed by *F. annosus* in 1962.
3. The stump and roots of a living tree infected with *F. annosus.*

In all cases, the presence of viable *F. annosus* fruiting bodies on the root collars was the criterion of infection. Trees killed in 1962 and the living infected trees were felled at the time of treatment and the resulting stumps were treated in the same manner as the stumps produced by the 1956 thinning. The following treatments were used:

1. Methyl bromide was applied to the plots (each plot consisted of a 10-x-10-foot square area with the stump at the center) in one of three ways:
   A. One pound of methyl bromide was evenly dispensed among four crowbar holes. The holes, each 20 inches deep, were located halfway between the corners of the plot and the stump center.
   B. One pound of methyl bromide was dispersed beneath a polyethylene tarp that covered the stump and the 10-x-10-foot square area. The tarp was trenched in along the four sides, but was elevated above the stumps and ground with branches to permit thorough dispersal of the gas (fig. 6).
   C. A combination of (A) and (B).

In treatments 1-B and 1-C the tarps were left in place for at least 24 hours.

2. SMDC was applied similarly, using a 1:10 aqueous dilution of the stock solution:
   A. Two hundred ml. were applied to each of the four 20-inch deep holes.
   B. One thousand ml. were sprinkled onto the stump top and duff, and the plot was covered with a polyethylene tarp.
   C. A combination of (A) and (B).

3. Check plots were treated as in (1) and (2) except that no fumigants were applied.

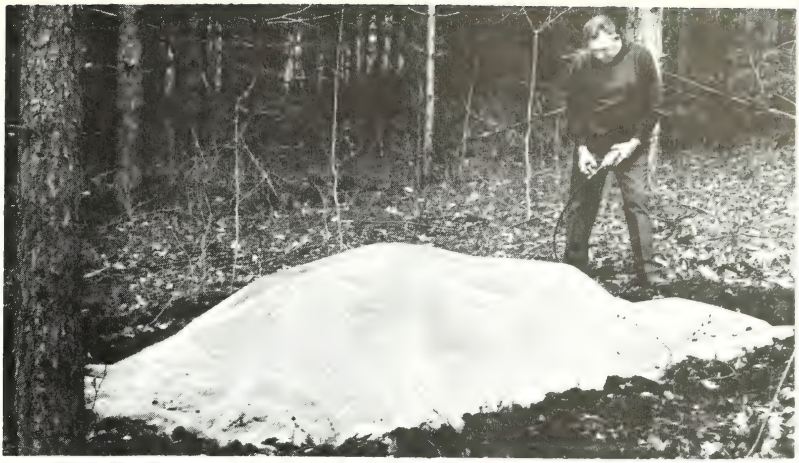


Figure 6. – Methyl bromide is being introduced into the air space between the trenched-in polyethylene tarp and the infected stump. Branches placed over the ground elevate the tarp above the stump.

At intervals of about 1 week, 2 weeks, 1 month, and 2 months after treatment, a root was removed from each stump, washed under tap water and aseptically split longitudinally. Chips taken from decay columns were plated onto a selective medium *(Kuhlman and Hendrix 1962).* Plates were examined after 7 days for the presence of *F. annosus* and *Trichoderma viride.*

Results

The results of this experiment are given in table 1. No apparent control was effected by SMDC under the conditions of this test. This was supported also by the record that the roots of adjacent living trees were not severely injured even though they were within the treatment zone. The methyl bromide treatments were more effective. *Fomes annosus* was not isolated in repeated trials from the old infected stump roots that had received treatment 1-C, but it was isolated from similar roots that had received treatments 1-A or 1-B. Treatment 1-C also appeared fairly effective in killing the fungus in roots of living infected trees and of trees killed recently. Based on these results, a second experiment was performed, using treatment 1-C only.

Table 1. – Effects of fumigation with methyl bromide or SMDC on *Fomes annosus* in roots of different stages of decay, July 1963
(+ = *Fomes annosus* isolated)

Plot No.	Root condition	Treatment[1]	Date of treatment	Date of isolation				
				June 26	July 12	July 26	August 7	August 14
			METHYL BROMIDE					
1	Well rotted	1-A	June 18	CON[2]	–	+	..	+
2	Well rotted	1-B	June 18	CON	+	..	..	..
3	Well rotted	1-C	June 18	CON	–	–	..	–
4	Dead (killed in 1962)	1-C	July 11	..	..	+	–	+
5	Live	1-C	July 17	..	..	..	+	..
			SMDC					
6	Well rotted	2-A	June 18	+	+	..	..	..
7	Well rotted	2-B	June 18	CON	+	..	..	..
8	Well rotted	2-C	June 18	CON	+	..	..	..
9	Dead (killed in 1962)	2-C	July 11	..	..	+	+	..
10	Live	2-C	July 17	..	..	..	+	..
			CHECK					
11	Well rotted	..	..	CON	+	..	..	..
12	Dead	..	..	..	..	+	+	..
13	Live	..	..	..	..	..	..	+

[1]Treatments refer to those described in text, Experiment 3.

[2]Contaminated.

Experiment 4

Effect of Methyl Bromide on Survival of F. annosus in Roots

Methods and Materials

Eighteen plots were established in a 30-year-old stand in south-central Connecticut in August 1963. The plantation, growing on a gravelly sandy-loam glacial till, had been thinned once in 1956.

The same three classes of root systems described in experiment 3 were treated. At intervals of 1 week, 2 weeks, 2 months, and 3 months after fumigation with treatment 1-C roots were excavated and isolations were made from selected portions. Check plots were tarped and trenched but not fumigated.

Results

After fumigation, *F. annosus* was not isolated from any of five well-rotted stumps and was recovered only once from the roots of a recently killed tree (table 2). Four of the five live trees yielded the fungus at some time during the study. Usually rot columns yielding *F. annosus* were surrounded by outer wood densely impregnated with pitch or resin. With few exceptions the aggressive saprophyte *Trichoderma viride* was isolated in pure culture when *F. annosus* was not.

The results of experiments 3 and 4 suggested that *F. annosus* could be eradicated more easily from some root tissues than from others, and that saprophytic fungi, notably *T. viride*, rapidly colonized fumigated roots previously inhabited by *F. annosus*. This was especially true for roots in an advanced stage of decay. These studies were expanded in 1964 to confirm the results of 1963 and to enable statistical analysis of the data.

Table 2. — Effects of fumigation with methyl bromide on survival of *Fomes annosus* in variously infected root tissues
(+ = *Fomes annosus* isolated)

Plot No.	Root condition	Treatment	Date of treatment	Date of isolation — 1963			
				August 28	Sept. 3	Oct. 16	Nov. 20
1	Well rotted	1-C	08/19/63	-	..	-	-
2	Well rotted	1-C	08/19/63	-	..	-	-
3	Well rotted	1-C	08/19/63	-	..	-	-
4	Well rotted	1-C	08/19/63	-	..	-	-
5	Well rotted	1-C	08/19/63	-	..	-	-
6	Live	1-C	08/19/63	-	..	+	+
7	Live	1-C	08/19/63	+	..	-	+
8	Live	1-C	08/19/63	-	..	-	-
9	Live	1-C	08/19/63	..	+	-	+
10	Live	1-C	08/22/63	..	+	-	-
11	Trees dead (killed by *F. annosus* in 1962	1-C	08/22/63	..	-	-	-
12		1-C	08/22/63	..	-	-	-
13		1-C	08/22/63	..	-	-	-
14		1-C	08/22/63	..	-	-	-
15		1-C	08/22/63	..	-	+	-
16	Old stump	Check	..	..	+	+	+
17	Living tree	Check	..	..	+	-	+
18	Dead tree	Check	..	..	+	+	+

Experiment 5

Effects of Methyl Bromide and SMDC on Survival of Fomes annosus in Variously Rotted Roots

Methods and Materials

Forty-five plots were installed in July 1964 in a 30-year-old stand that had been thinned in 1959. Fifteen plots (five for each of the three root conditions) were used for each of three treatments: namely, methyl bromide, 1 pound in the ground and 1 pound under the polyethylene tarp (1-C); SMDC, 800 ml. in the ground and 1,000 ml. on ground and stump under tarp (2-C); and the checks, tarped but not fumigated.

Three to 4 weeks after treatment, the root systems were

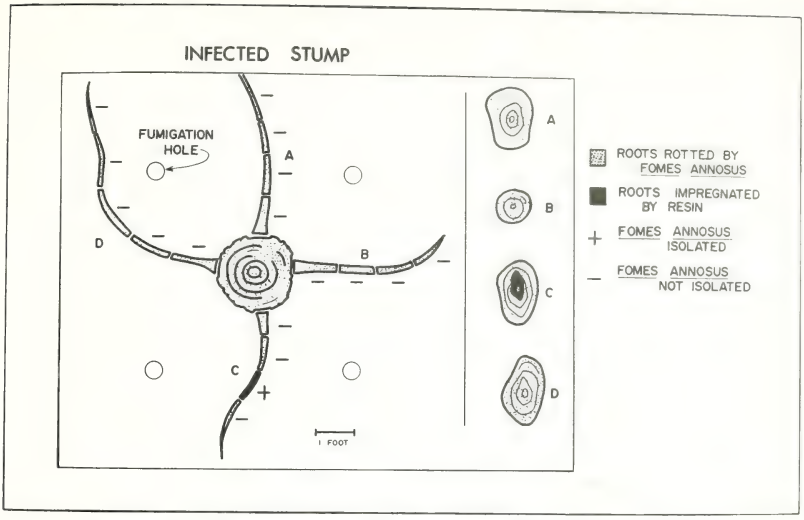


Figure 7. – Diagrammatic presentation of one of the well-rotted stumps treated with methyl bromide in experiment 5. The four major roots are shown with respect to the fumigation holes and to the points of isolation.

excavated, and the four major roots were measured, diagrammed with respect to the fumigation holes (fig. 7), and described as to their condition of decay. Over 2,700 isolations were made from these roots in the manner described in experiment 3.

Results

The results are summarized in table 3. An analysis of variance indicated that differences in stump conditions and in treatments were highly significant, while the interaction between stump condition and treatment was not. Tukey's test was used to determine significant differences among means for treatment and stump condition.

At the 5-percent level, untreated, rotted, dead, and live root tissues yielded significantly different percentages of *F. annosus*. None of the treatments differed significantly from each other when applied to well-rotted stumps; methyl bromide significantly reduced *F. annosus* in live tree roots; and both methyl bromide and SMDC treatments significantly reduced *F. annosus* in dead tree roots.

Table 3. – The percentage of isolation chips that yielded *Fomes annosus*. Each figure represents the percentage of over 300 chips.

Treatment	Chips yielding *Fomes annosus*, by root condition		
	Well rotted	Live	Dead
	Percent	*Percent*	*Percent*
Checks	10.7*	41.7	76.2
SMDC (Vapam) (2-C)	10.7	22.0	29.7
Methyl bromide (1-C)	2.3	1.8	12.05

*Lines connect values *not* significantly different from each other at the 5% level.

In all cases, the methyl bromide treatment was more effective than SMDC, and the SMDC treatment was somewhat more effective than no treatment.

In most cases where *F. annosus* was isolated from methyl-bromide-treated roots less than 4 inches in diameter, the rot columns were surrounded by outer wood densely impregnated with resin. Occasionally *F. annosus* was cultured from some of the roots over 6 inches in diameter. As in earlier experiments, *Trichoderma viride* was isolated frequently from fumigated roots, occasionally from the same chips that yielded *F. annosus*, but most consistently from well-rotted roots where *F. annosus* was killed by fumigation. *T. viride* also developed in abundance on the bark of treated roots – especially when the plots were covered with a polyethylene tarp for several days.

Experiments 3, 4, and 5 indicated that treatment of infected roots and stumps with fairly high concentrations of methyl bromide (2 pounds per plot and in most cases under a polyethylene tarp) markedly reduced *F. annosus* in these root systems and encouraged the rapid colonization of these tissues by other saprophytic fungi, especially *T. viride*. However, it remained to be seen whether the line-plot method of application and the dosages worked out under study I would be equally effective.

Experiment 6
Line Plot Fumigation Between Infected and Living Trees

Methods and Materials

In June 1963, two plots were established by injecting fumigant into 20-inch-deep holes at 1-foot intervals along a line separating, in each case, two apparently healthy 25-year-old red pines from adjacent stumps that bore viable sporophores. In one plot, 1 pound of methyl bromide was dispensed evenly among 9 holes; in the other SMDC was applied at the rate of 200 ml. of 1:10 dilution per hole. Four months later the root systems of trees and stumps were excavated and diagrammed and isolations for *F. annosus* were made.

Results

The results of isolation are indicated on figures 8 and 9 as positive (+) or negative (-). As before, methyl bromide (fig. 8), at the concentrations used, appeared more effective than SMDC (fig. 9) in killing the roots of the living trees and in reducing *F.*

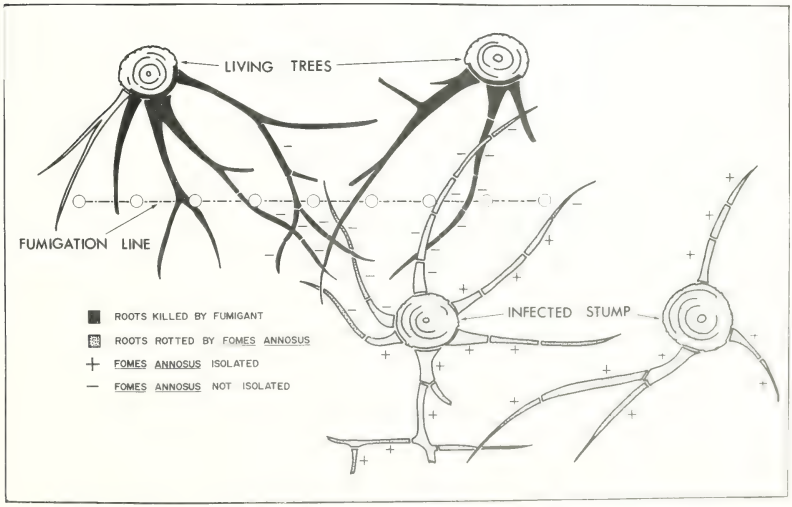


Figure 8. – The effects of methyl bromide on living roots and on *F. annosus* in roots of infected stumps.

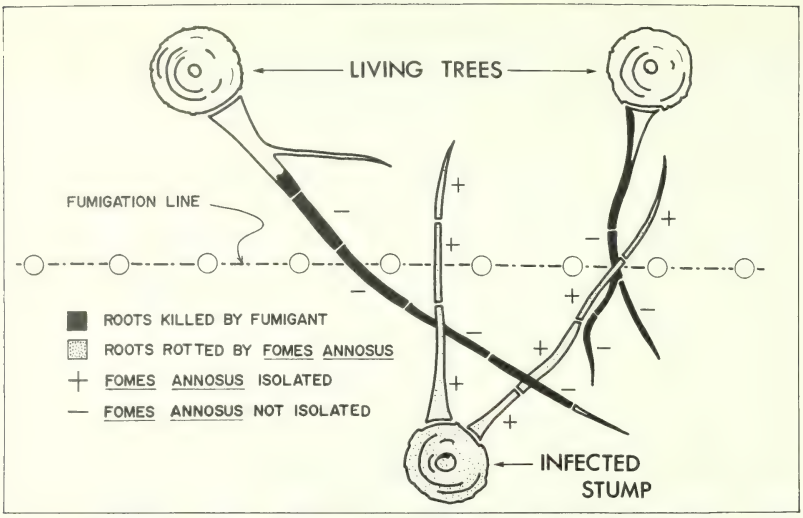


Figure 9. – The effects of SMDC on living roots and on *F. annosus* in roots of infected stumps. Roots killed by the fumigant are colored black, isolation results are shown as positive (+) or negative (–).

annosus in infected root systems. As noted in earlier trials conducted at this season of the year, injury to the boles above ground occurred in the methyl bromide plot.

STUDY III

ESTABLISHMENT OF BARRIERS BY USING SOIL FUMIGATION

The experiments described in studies I and II provided the supporting information needed for a test of the original hypothesis that zones of roots killed by fumigation and then colonized by saprophytic fungi would prevent spread underground of *Fomes annosus.* Armed with this information, we began an experiment to test the efficacy of fumigation as a control of *F. annosus.*

Experiment 7

Fumigation of Infection Centers

Methods and Materials

Twelve infection centers in red pine plantations located in New York, New Hampshire, Connecticut, and Rhode Island were selected for treatment in the fall of 1967 based on the following criteria:

1. Activity (trees currently dying from *F. annosus).*
2. Discreteness (centers separated from each other by at least 10 rows of healthy trees).
3. Size (perimeter of centers restricted to 4 chains or less).

All stumps and trees in and surrounding the infection centers were examined for fruiting bodies of *F. annosus*, and the centers were delineated on this basis. The fumigation line was established at least one healthy tree (without fruiting) outside of the outermost tree or stump bearing fruiting bodies. Methyl bromide, at the rate of 1 pound per every 8 linear feet, was dispensed into 20-inch-deep holes punched at 1-foot intervals along the fumigation line. The positions of the stump and trees in each plot were mapped and their disease conditions were noted (fig. 10).

Six months after treatment the effectiveness of the fumigant was assessed in several plots. All the roots in a zone 2.5 to 3.5 feet on either side of the fumigation line had been killed, and little injury was apparent above ground on stems 4 feet or more from the line. But the spacing of several plantations necessitated injecting the fumigant closer than 4 feet from some trees. And 9 months after treatment in such stands, injury to trees adjacent to the fumigant line were evident. Indeed several trees 2 to 3 feet from the line were damaged severely and probably will die. Underground, the bark had deteriorated on many roots, and many of them were colonized by stain fungi. Each of these plots, along with other plots yet to be established, will be examined annually to determine if breakover occurs and, if so, how or why.

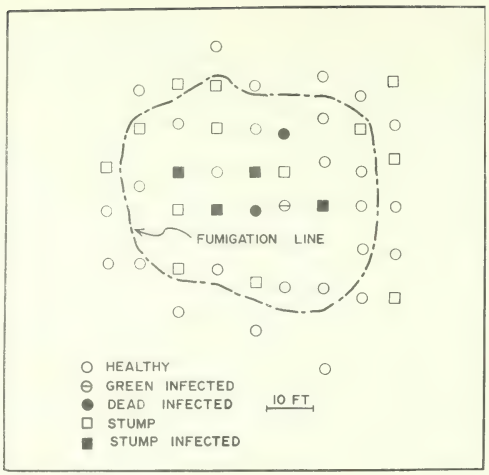


Figure 10. — A map of one infection center showing the location of the fumigation line in relation to the infected trees and stumps. All infected trees and stumps bore fruit bodies of *F. annosus*.

DISCUSSION

These studies demonstrated that soil fumigants can be used effectively to kill healthy roots of red pine in bands or zones of quite consistent widths. It was shown also that *Fomes annosus* was not selectively favored by the temporary reduction of normal saprophytic fungi in the soil but was itself markedly reduced in treated root systems previously infected. In addition, isolations from fumigated soil and roots revealed the rapid recolonization and buildup of saprophytes, especially *Trichoderma viride*. Studies elsewhere have shown that *T. viride* was highly resistant to fumigation with methyl bromide and rapidly repopulated fumigated soil *(Wensley 1953)*.

These studies pointed out the difficulty of eliminating *F. annosus* from certain portions of infected root systems. This was probably attributable to poor penetration of fumigant through tissues impregnated with resin. Resinosis also has been reported to inhibit or restrict the movement of *F. annosus* in wounded roots *(Wallis 1961)*. We observed repeatedly that a root was almost never uniformly resinous. Often a thoroughly impregnated section of a foot or so in length ended abruptly in either decayed or sound wood. Fumigation of such roots

resulted in eradication of *F. annosus* from the decayed portions, and rapid colonization of both the non-resinous decayed and sound portions by other fungi, particularly *Trichoderma.*

Large roots, primarily those greater than 6 inches in diameter, sometimes still harbored the fungus after fumigation. The only roots of this size encountered in these studies were restricted to within 2 feet of the stump.

Several factors are still unresolved. One of these concerns the time it will take for roots from adjacent trees to grow across the fumigated zone and re-establish contact with infected tissues. Another factor concerns the fate of the trees bordering the fumigation line, especially those trees within the 4-foot zone. A number of trees in this zone probably will die, and many more will be injured severely and become liable to bark beetle attack. Some stem injury and beetle attack occurred even on trees more than 4 feet distant. How trees with but half a root system alive will fare under drought conditions or even under normal stand competition remains to be seen.

Another point yet unresolved is the efficacy of delineating infection centers by the presence of sporophores rather than through actual isolation. This was done for several reasons. Our observations of a number of infection centers in the Northeast revealed that although a red pine may be infected and not bear fruit bodies, roots several feet from the tree on the side opposite the infection center usually are not colonized until after conks appear on the tree. Also, the technique must be one usable by foresters without benefit of isolation results. The readily recognized conks of *F. annosus*, their usually rapid development on infected trees – particularly in the fall – and the inclusion of a surrounding row of apparently healthy trees within the treated area ought to be an adequate method of delineating the infected area. The success or failure will be revealed with time.

The inconsistent results produced by SMDC (vapam) probably does not reflect the nature of the material but rather the concentration used. The amount employed was based upon early recommendations developed elsewhere for different purposes. More recent recommendations have called for applying

the material at greater concentrations *(Neely and Himelick 1965, 1966).* What should be borne in mind here is that these studies were not intended to compare materials, but to test the concept of a barrier zone composed of root tissue rendered unsuitable for colonization by *F. annosus.* If the concept proves sound, then further testing should be done with a variety of materials and concentrations.

We have not attempted to cost the materials or manpower required to locate, delineate, and treat infection centers. But it is probable that this technique, if successful, would be feasible only in stands where considerable values are at stake. Arboreta, seed orchards, recreational areas, and perhaps certain watersheds might warrant this treatment. Also, certain forest plantations in which preventive stump treatments have been made would be good prospects for fumigation treatment. In such stands infection centers would very likely arise through infection of overlooked stumps or of stumps whose treated surfaces had been scraped or damaged and consequently might be limited in number, small, and discrete and thus suitable for fumigation treatment.

■

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by David G. Martens

FLOORING COSTS

A comparison of installation and maintenance costs for three types of residential flooring

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FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
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FLOORING COSTS

A comparison of installation and maintenance costs for three types of residential flooring

Introduction

INITIAL installation cost, annual maintenance cost, and total long-term cost are important in the purchase of flooring products. Before deciding on a flooring material, the prudent buyer will consider each of these in relation to his personal desires. From these evaluations, he will then be able to select the flooring material that is best suited to his individual needs.

Unfortunately very little information about these cost factors has been made available to the potential buyer. Most of the information that is available is in manufacturers' claims about their own products. When the buyer attempts to compare these claims, he finds that many of them are conflicting. Consequently he is unable to make the objective comparisons he needs to make to determine the most appropriate material for his individual situation.

In an attempt to help alleviate this problem, we recently conducted a study to obtain unbiased information about the various flooring materials used under residential conditions. From our data, we concluded that, when compared with composition tile and wall-to-wall carpeting, hardwood flooring has the lowest annual maintenance cost and lowest long-term cost. From the information contained in this report, the prospective buyer can make his own comparisons to determine the flooring material that suits him best.

The Study

Our study was designed to determine and compare annual and long-term flooring costs based on the initial installation cost, the maintenance cost, and the wear life of the flooring material. We also attempted to determine the time and effort required to maintain each of the principal types of flooring material used under residential conditions.

Although single-family homes constitute the largest percentage of dwelling units, they vary greatly in size, type of structure, and costs. Also, accurate long-term records of wear life and major maintenance costs are very difficult to obtain for single-family homes, because of the relatively rapid owner turnover. Consequently we decided to use apartment buildings for our study because they represent a more standardized and compact unit to work with and because more accurate maintenance information is available for them.

Nine cities – Atlanta, Boston, Chicago, Denver, Houston, Los Angeles, New York, St. Louis, and Washington – were selected for inclusion in the study (fig.1). They accounted for over half

Figure 1. – Cities selected for sampling in maintenance survey.

of the approved apartment building permits issued in the United States in 1962. We felt that this range of sampling would allow for the variation in flooring materials used throughout the Nation and would help us measure flooring costs and wear under different living and climatic conditions.

In each city, eight apartment buildings were selected for detailed study. An attempt was made to use four high-rise buildings and four garden-type buildings, two of each under 10 years old and two over 10 years old. This sampling procedure took into account different construction methods and newer flooring materials as well as the older types. The data were collected and analyzed in two phases.

Phase I

Phase I was a personal interview with the owner or manager of each apartment building, to gather detailed information about their experiences with the various types of flooring. From this information, we determined the installation costs of the various types of flooring, how often they were maintained by the owner, the cost of this maintenance, and the actual wear life. We also obtained information about room dimensions and flooring specifications.

Phase II

In phase II, a subsample of individual apartment tenants in each building was selected for interview by mailed questionnaire. From this questionnaire we found out the time and effort the average housewife spends to maintain her floors, the materials required for maintenance, and her opinions of the different flooring materials. From these observations we were able to estimate the time, effort, and materials required to maintain each of the principal types of flooring.

The data were analyzed and evaluated from the standpoint of a single-family-home owner. That is, the data collected from the building owner were combined with the data collected from the apartment tenant to estimate the installation and maintenance costs that the owner of a single-family home would experience.

Although several rooms in each apartment were investigated, this report covers only the information collected for living rooms. Later reports will deal with bedroom and dining room areas and comparisons between rooms.

APARTMENT BUILDING OWNER

The information obtained from the building owners – installation costs, actual wear life, and maintenance costs – has been condensed into table 1. The types of flooring materials included were asphalt tile, vinyl asbestos tile, hardwood strip, hardwood block, nylon carpet, and wool carpet. For comparison these were combined into composition tile (asphalt and vinyl asbestos), hardwood (strip and block), and carpet (nylon and wool).

Composition tile had the lowest average installation cost – $35 per 100 square feet – and an average wear life of 17.7 years. Hardwood flooring had the highest average installation cost – $60 per 100 square feet – but had a total wear life of over 50 years. Carpet had an installation cost close to that of hardwood – $58.61 per 100 square feet – but had the lowest average wear life, 7.5 years.

Also included in the reported cost of hardwood flooring was a complete resanding and refinishing every 9.5 years at an average cost of $11.97 per 100 square feet. The average total annual costs per 100 square feet to the building owners for the various types of flooring materials were: $2.726 for composition tile, $3.022 for hardwood, and $10.458 for carpet.

Table 1. – Apartment owners' long-term cost of living room floors

(Based on interviews with 72 building managers or owners)

Type of flooring material and cost element	Item
Asphalt tile:	
Installation cost/100 square feet	$27.50
Wear life, years	16.7
Minor maintenance cost/100 square feet/year	$ 0.503
Total annual cost/100 square feet	$ 2.130
Vinyl asbestos tile:	
Installation cost/100 square feet	$42.50
Wear life, years	18.7
Minor maintenance cost/100 square feet/year	$ 1.036
Total annual cost/100 square feet	$ 3.321
Hardwood strip flooring:	
Installation cost/100 square feet	$60.00
Wear life, years	50+
Major maintenance cost/100 square feet	$11.97
Average frequency of major maintenance, years	9.5
Minor maintenance cost/100 square feet/year	$ 0.576
Total annual cost/100 square feet	$ 3.036
Hardwood block flooring:	
Installed cost/100 square feet	$60.00
Wear life, years	50+
Major maintenance cost/100 square feet (same as strip)	$11.97
Average frequency of major maintenance, years (same as strip)	9.5
Minor maintenance cost/100 square feet/year	$ 0.549
Total annual cost/100 square feet	$ 3.009
Nylon carpet:	
Installation cost/square yard	$ 4.49
Installation cost/100 square feet	$49.88
Wear life, years	6
Major maintenance cost/100 square feet/year (carpet cleaning)	$ 2.517
Average frequency of major maintenance, years	1.62
Total annual cost/100 square feet	$10.830
Wool carpet:	
Installation cost/square yard	$ 6.06
Installation cost/100 square feet	$67.33
Wear life, years	9
Major maintenance cost/100 square feet/year (carpet cleaning)	$ 2.606
Average frequency of major maintenance, years	1.75
Total annual cost/100 square feet	$10.087

APARTMENT TENANTS

The maintenance information obtained from the apartment tenants tells a somewhat different story. Although composition tile floors were the least expensive for the owners to install, they were reported to be the most expensive for the tenants to maintain. Data from the questionnaires indicated that a tenant spends $9.89 per 100 square feet per year for floor maintenance in a living room completely covered with composition tile. This compares with $4.21 for maintaining a hardwood floor. Wall-to-wall carpet costs the tenant $7.98 to $8.56 per 100 square feet per year, depending on whether it was owned by the tenant or the building owner. By far the greatest part of the

Table 2. – Average minor maintenance costs[1] (professional carpet cleaning separate) for living room floors, by type of flooring and rug-coverage area

(In dollars/100 square feet/year)

Floor type	Percent of rug coverage				
	0-20	20-40	40-60	60-80	80-100
Composition tile	9.89	3.91	3.56	2.17	2.21
Hardwood flooring	4.21	1.32	4.57	1.82	1.90
Carpet	–	–	–	–	1.63
Professional carpet-cleaning costs	0	1.16	2.20	2.32	6.35

[1] Based on responses from 760 housewives. Minor maintenance costs were calculated from maintenance frequencies and type of maintenance materials used as reported by the housewives together with maintenance material prices and expected coverages reported by the manufacturing companies.

Table 3. – Average minor maintenance costs for living room floors, by type of flooring and rug-coverage area

(In dollars/100 square feet/year)

Floor type	Percent of rug coverage				
	0-20	20-40	40-60	60-80	80-100
Composition tile	9.89	5.07	5.76	4.49	8.56
Hardwood flooring	4.21	2.48	6.77	4.14	8.25
Carpet (wall-to-wall)	–	–	–	–	7.98

carpet expense is for professional carpet cleaning, which averaged $6.35 per 100 square feet per year. A complete breakdown of the tenants' maintenance expenses, showing minor maintenance and professional carpet-cleaning cost separately, is given in table 2. The combined maintenance costs to the tenant are given in table 3.

SINGLE-FAMILY-HOME OWNERS

Total Annual Costs

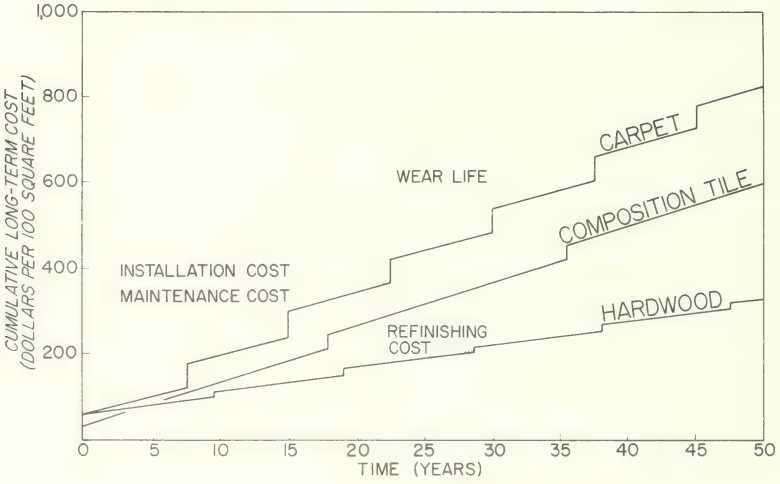
We combined the cost to the building owner with the cost to a tenant to estimate total flooring costs for a single-family-home owner. The owner costs were the installation cost in relation to wear life, plus sanding and refinishing costs. Tenant costs were those of maintenance only.

Table 4. — Estimated long-term flooring costs in the living room for single-family-home owners, by type of flooring

Type of flooring material and cost element	Item
Composition tile:	
Installation cost/100 square feet	$35.00
Wear life, years	17.7
Minor maintenance costs/100 square feet/year	$ 9.89
Total annual cost/100 square feet/year	$11.87
Hardwood flooring:	
Installation cost/100 square feet	$60.00
Wear life, years	50+
Major maintenance cost/100 square feet every 9.5 years	$11.97
Minor maintenance cost/100 square feet/year	$ 4.21
Total annual cost/100 square feet/year	$ 6.67
Carpet (wall-to-wall):	
Installation cost/square yard	$ 5.28
Installation cost/100 square feet	$58.61
Wear life, years	7.5
Minor maintenance cost/100 square feet/year (professional cleaning)	$ 6.35
Minor maintenance cost/100 square feet/year	$ 1.92
Total annual cost/100 square feet/year	$16.09

In annual cost per 100 square feet, hardwood floors showed a definite economic advantage: $6.67 compared to $11.87 for composition tile and $16.09 for wall-to-wall carpet. Thus hardwood floors cost little more than half the cost of composition tile and less than half the cost of wall-to-wall carpet. A tabulation of estimated costs to a single-family-home owner is given in table 4, and a graphic presentation of these costs over time is given in figure 2.

Figure 2. — Estimated long-term floor costs for individual homeowners.



Maintenance Time

Costs alone do not provide a complete picture. The time spent maintaining the different flooring materials is also important. The questionnaires received from the tenants indicated that the average housewife spends 44.4 hours per 100 square feet per year maintaining composition tile, compared to 21.8 hours for hardwood flooring and 14.1 to 21.1 hours for wall-to-wall carpet. The average time spent on wall-to-wall carpet was 16.0 hours per 100 square feet per year. All times are shown in table 5.

Table 5. — Average time spent for maintenance on living room floors, by type of flooring and rug-coverage area

(In hours/100 square feet/year)

Floor type	Percent of rug coverage				
	0-20	20-40	40-60	60-80	80-100*
Composition tile	44.4	34.0	41.6	52.1	21.1
Hardwood flooring	21.8	17.9	34.4	28.2	14.1
Carpet	—	—	—	—	14.1

*Weighted average of all flooring types with 80-100-percent rug coverage is 16.0 hours/100 square feet/year.

Flooring Preferences

Housewives' relative preferences for the different types of flooring materials were also studied. This was done by analyzing their answers to the question: "If you decided tomorrow to build a new home, what type of flooring or floor covering would you prefer for the living room?" When the answers were analyzed, it soon became apparent that housewives' preferences between hardwood and carpet were closely associated with the type of flooring material they had been living with. Approximately 65 percent of the people who had hardwood floors said they would prefer hardwood in a new home; the rest preferred wall-to-wall carpet. Of the people who had wall-to-wall carpet, about 67 percent said they wanted carpet; the rest wanted hardwood floors.

But of the people who had composition tile, only 10 percent said they would put it in the living room of a new home. About 40 percent preferred hardwood, and 50 percent preferred wall-to-wall carpet.

Hence 10 percent of all respondents had composition tile but only 4 percent of all respondents would put it in their new home. Similarly, 66 percent of the respondents had wall-to-wall carpet or a floor more than 60 percent covered with carpet, but only 57 percent of the total respondents said that they would prefer wall-to-wall carpet in a new home. Hardwood floors were represented by 24 percent of the respondents, but 38 percent of

Table 6.—Preference for living room floors, by type of flooring and rug-coverage area

(In percent)

Type of flooring respondents now have	Percent of total	Floor type preferred in a new home				
		Composition tile	Hardwood flooring	Carpet wall-to-wall	Other	Total
Composition tile (less than 60% covered)	10	10	39	51	0	100
Hardwood flooring (less than 60% covered)	24	(*)	65	33	2	100
Carpet wall-to-wall (over 60% covered)	66	4	28	67	1	100
Percent of total	100	4	38	57	1	100

*Less than 1 percent.

the respondents said that they would prefer hardwood in a new home. All of the preference data are presented in table 6.

Opinions about Ease and Expense of Maintenance

We also attempted to obtain the housewives' opinions about the ease and expense of maintaining the various types of flooring. However, the data turned out to be rather inconclusive.

The closest that the respondents came to a consensus was in designating wall-to-wall carpet as the easiest to care for (59

Table 7. — Opinions of housewives about ease and expense of maintaining living room floor surfaces, by type of flooring, in percentage of response

Rating	Composition tile	Hardwood flooring	Large rug on wood or tile	Wall-to-wall carpet	Total
Easiest	6	20	15	59	100
Most difficult	33	39	14	14	100
Cheapest	28	26	12	34	100
Most expensive	12	32	8	48	100

percent of the respondents so indicated, as shown in table 7). For the other types of flooring, no clear pattern of opinion could be found in the response to the question about maintenance ease or expense.

Discussion & Conclusions

Every attempt was made in this study to obtain typical or representative samples from the real world. We wanted data on the actual costs encountered and the actual procedures used by the average housewife in maintaining different flooring materials. For instance, we found that over 40 percent of the housewives who had hardwood floors wet-mopped them. This procedure, though not recommended by manufacturers, does occur in real life and must be accounted for in any estimate of maintenance time. Waxing was also performed much more frequently than manufacturers recommend or believe to be necessary.

We collected data on only medium-rental apartments because neither luxury nor low-rent housing could be considered typical. We also used both high-rise and garden-type apartments to take into account differences in building construction and flooring types.

Every attempt was made to eliminate bias. We believe the results are representative of the true relative costs for maintaining the various types of flooring materials used under residential conditions.

APARTMENT BUILDING OWNERS

The apartment owner is a businessman; so factors affecting operating costs such as installation cost, wear life, and maintenance costs of the floors are important to him.

Installation Costs

The estimates of installation costs used for smooth-surface floors in this report are not those given by the building owner.

Since many of these floors were installed over 15 years ago, the quoted costs were unrealistic for today's conditions.

For tile floors the installation costs used were those published by the Wharton School of Finance and Commerce[1] in a recent study.

For hardwood flooring, after consulting with hardwood flooring manufacturers, flooring contractors, and builders, we selected the installed price of $60.00 per 100 square feet. We believe this figure represents the majority of installations. Several companies quoted prices in the range of $45.00 to $58.00.

For wall-to-wall carpet the installed cost is that quoted by the building owners. Because of the relatively short life of this material, these prices were considered to be current. The costs used included carpet, pad, labor, and accessories such as door strips. The total installation cost for nylon carpet averaged $4.49 per square yard, and the cost for wool carpet averaged $6.06 per square yard.

Wear Life

The wear-life values reported by the building owners are very close to those expected by the manufacturers. The Asphalt and Vinyl Tile Institute[2] estimates that wear life is 15 years for asphalt tile and 20 years for vinyl asbestos. These correspond closely with the values found in this study.

The wear life of hardwood flooring is generally considered to be the life of the building. However, the reported frequency of complete resanding and refinishing every 9.5 years is greater than most hardwood flooring manufacturers predict.

The reported wear life for carpet is slightly higher than that predicted by the general rule of thumb of 1 year of wear life per dollar of installation cost per square yard. This additional life may be due to better maintenance

[1] Parks, George M. THE ECONOMICS OF CARPETING AND RESILIENT FLOORING: AN EVALUATION AND COMPARISON. Univ. Pa. Wharton School of Finance and Commerce, Indust. Res. Unit, Philadelphia, Pa. 87 pp., illus. 1966.

[2] Asphalt and Vinyl Tile Institute. SELECTING A FLOOR. Progressive Architecture 44(12): 146. 1963.

nance methods, or to lower acceptable appearance levels used by the apartment building owners to determine when the carpets need replacement.

Maintenance Costs

Maintenance costs to the building owner generally result from getting a vacated apartment ready for new tenants. So these costs are related to tenant turnover. In general, the turnover is low in the Northeast and parts of the South where hardwood and asphalt tile are the principal flooring materials. In the rest of the Nation, especially the West, turnover is high; in these areas carpet and vinyl asbestos are more commonly used. The difference in turnover obviously has some effect on the relative maintenance cost for the different types of flooring.

The average maintenance cost for vinyl asbestos flooring was also higher because of the policy of one building owner who periodically waxed and buffed the floors while the tenants were in the apartments. Although his practices were logical, his costs were higher; and they did raise the average. If his costs were not included, the average maintenance cost for vinyl asbestos would have been similar to that for asphalt tile.

Most building owners felt they could clean the carpets and in some cases lift the pile for 4 to 4.5 cents per square foot, and some indicated they could do it for as little as 3 cents. Others hired the cleaning done, and their costs were slightly higher.

In addition to waxing and buffing the floors, the building owners who had hardwood floors had the cost of complete resanding and refinishing. This cost is comparable to the cost for complete replacement of the other types of flooring. It would also occur to the single-family-home owner, so it was included in the estimate of his costs. Note that the 9.5-year frequency was the average for the owners who did refinish their floors. Several owners had hardwood floors much older than 9.5 years but had never resanded or refinished. For example, one building had a stained oak parquet floor that was over 20 years old and had not been refinished.

Although the total flooring cost will differ from building to building, the relative owner costs of the various types of

flooring should remain constant – hardwood and composition tile were the least expensive and carpet the most expensive.

APARTMENT TENANT

The apartment tenant, in contrast to the apartment owner, is not concerned with installation cost or wear life of the flooring material. Her main expense, other than professional carpet cleaning, is the out-of-pocket cost for maintenance materials such as waxes, strippers, shampoos, and spot cleaners. These costs are referred to in this report as minor maintenance costs.

Minor Maintenance Material Costs

Table 2 lists minor maintenance costs per 100 square feet of room area, and cost of professional carpet cleaning is shown separately. The percent of rug coverage refers to the percent of room area covered by rug or carpet. The values given under 0 to 20 percent are costs for maintaining only smooth-surface flooring. All times and costs for maintaining any rugs in the 0-to-20-percent class were disregarded because these would be small throw rugs, which could be easily moved and washed in a washing machine. Likewise, the values given in the 80-to-100-percent group pertain only to the cost of maintaining carpet in a room. Any costs reported for smooth-surface floors were disregarded in this group because they would represent a small area around the edge of the room or under furniture.

For example, the $9.89 for composition tile and the $4.21 for hardwood are costs per year to wax and strip 100 square feet of room area having these types of floors. The $3.91 for composition tile 20-to-40-percent covered is for both wax and other materials used on the floor and for shampoo and spot remover used on the carpet. However, the $2.21 for composition tile 80-to-100-percent covered is only for shampoo and spot remover used on the carpet at home. None of this cost pertains to composition tile because none or very little of it was showing. All of these costs are based on the frequency of maintenance, the types of products used and their prices, and the coverage obtained from these products.

Professional Carpet-Cleaning Costs

The professional carpet-cleaning costs refer to the average costs to the tenants for hiring someone to clean their carpet either in their apartment or at a cleaning establishment. A cost of $8.32 per 100 square feet of carpet per year was the average cost for the housewives who had their carpets professionally cleaned, regardless of carpet size. However, not all housewives had their carpets professionally cleaned. For instance, the average cost for those carpets that were cleaned in the 20-to-40-percent coverage class was $8.84 per 100 square feet of carpet per year. However, only 44 percent of the carpets were professionally cleaned, so the average for all carpets was $3.86 per 100 square feet of carpet per year. In addition, since carpet made up only 30 percent of the room area in that category, the cost per 100 square feet of room per year was only $1.16. The 44 percent of the carpets in the 20-to-40-percent category that were professionally cleaned compares to 73 percent in the 80-to-100-percent category. This would be expected because the larger carpet is more difficult for the housewife to clean by herself.

Also the fact that these values are given in dollars per year does not mean that every housewife has her carpet professionally cleaned every year. Many were professionally cleaned only once every 2 or 3 years, and were shampooed at home in between. As we noted before, many were never professionally cleaned, especially the smaller rugs.

Combined Minor Maintenance Costs

The combined maintenance costs of the tenants given in table 3 are what would be expected when the values in table 2 are combined. The minor maintenance cost of hardwood floors ($4.21 per 100 square feet) is about half that of either of the other two types of flooring; composition tile had a cost of $9.89 and wall-to-wall carpet (80-to-100-percent covered) averaged $8.27 per 100 square feet per year.

The maintenance costs for wall-to-wall carpet (80-to-100-percent cover) are the most reliable because approximately 50

percent of the tenants responding had floors in their living rooms that were over 80 percent covered with rug or carpet. The fewest observations were obtained in the low rug-coverage classes for composition tile, and the value of $9.89 for composition tile 0-to-20-percent covered is based on only 24 respondents. So less confidence can be placed in it than in the values for the other floor types and coverage classes.

SINGLE-FAMILY HOME OWNER

The floor costs for a single-family-home owner (table 4) are of course only estimates. We realize that a housewife in an apartment may not care for those floors as well as she might care for the floors in a home she owned. However, we believe that the relative differences in cost among the various floor types should remain about the same. There is no reason why she should treat one floor type better than another if she owned a home rather than rented, or vice versa. Consequently, all values in table 4 may be lower (or possibly even higher) than would actually occur in a single family home, but the relative ratings of the flooring types should not change.

Total Floor Costs

Hardwood floors have a distinct economic advantage of total cost (fig. 2). Under the conditions encountered in this study, a homeowner with a 15-by-20-foot living room would save $750 over the period of a 25-year mortgage if he had hardwood floors instead of wall-to-wall carpet; he would save $484 if he had hardwood floors instead of composition tile. This is only the savings for the 300 square feet in the living room. It does not include the other floor area in the home.

Maintenance Time

The average maintenance time spent on the different types of flooring varied considerably among materials. The high time values for composition tile were the result of frequent wet-mopping, buffing, and waxing. It seems that the housewife takes considerably more time and effort to keep composition tile at

the appearance level she wants than it does for the other two types of flooring. The fact that the living room is an area where a high appearance level is desired could explain the high frequency of maintenance on tile. Maintenance time on hardwood flooring and wall-to-wall carpet were approximately the same; carpet averaged about 5-1/2 hours less per year. The 14.1 hours for wall-to-wall carpet compared to 21.1 hours for composition tile 80-to-100-percent covered with carpet (table 5) indicates that less cleaning time may be spent on carpet owned by landlords than on carpet purchased by housewives. However, a comparison of wall-to-wall carpet and hardwood floors 80-to-100-percent covered indicates no difference.

Flooring Preferences

Housewives' flooring preferences (table 6) indicate that in general either the housewives selected and have the type of flooring they prefer, or that they have convinced themselves that the type of floor that they now have is really what they would prefer if they were given a choice. Use of these data to predict national or regional preferences would not be valid because preferences seem to depend on what type of flooring material the respondents have at the time the survey is taken. For example, a survey of apartment dwellers in Los Angeles who have hardwood floors would probably indicate a preference for hardwood in that area. Yet Los Angeles has traditionally been predominantly a carpet area. However, the correlation between the type of flooring housewives have and the type they prefer could be an indicator of housewives' satisfaction with the various types of flooring.

Opinions about Ease and Expense of Maintenance

The portion of the study dealing with housewives' opinions about the ease and expense of maintaining the different types of flooring was included for two reasons. First, we wanted to find out if there were predominant feelings among housewives that certain flooring materials were easiest or most difficult, cheapest or most expensive, to maintain. Second, we wanted to

find out how closely these opinions were related to actual time and cost data determined by the study.

On the first point, we found that apparently housewives have no strong feelings about the ease and expense of maintaining the different floor coverings.

And on the second point, their opinions did not agree very well with the figures that they as a group provided. The combined categories of large rug on wood or tile and wall-to-wall carpet received about three-fourths of the votes for easiest to maintain. This does parallel our findings. However, this same combination received about 30 percent of the votes for most difficult, and this does not agree. Likewise, 40 percent of the housewives indicated that hardwood floors were the most difficult to maintain, yet those apparently take less than one-half as much time to maintain as composition tile. Almost 50 percent of the votes for least expensive to maintain went to the large rug or carpet categories, yet these were found to be the most expensive. And over 30 percent of the votes for most expensive went to hardwood, which was actually the least expensive.

Summary

Data from our study showed that hardwood floors in living rooms cost less than floors covered with composition tile or carpet. This is true both in terms of yearly cost and long-term cost. Hardwood floors also have a wear life much longer than that of the other flooring materials.

Wall-to-wall carpet, although twice as expensive as hardwood, has the advantage of requiring less time to maintain; but the difference is not large.

Composition tile is the cheapest floor material for an apartment owner to have in his building; but tenant maintenance costs are high, and tenant preferences indicate that tile is not as well received as hardwood, which is only slightly higher in total cost. Wall-to-wall carpet is by far the most expensive to the apartment building owner although it is well received by the tenants.

Overall, in yearly cost, long-term cost, wear life, maintenance time, and preference, hardwood floors appear to be the most practical for the single-family-home owner, the apartment tenant, and the apartment building owner.

Table 8.—Number of observations in each cell

Type of flooring	Rug coverage, in percent					Total
	0-20	20-40	40-60	60-80	80-100	
Composition tile	24	9	39	32	105	209
Hardwood flooring	60	37	88	86	185	456
Wall-to-wall carpet	–	–	–	–	95	95
Total	–	–	–	–	–	760

Table 9. – Range[1] of average times spent for maintenance on living room floors, by type of flooring and rug-coverage area

(In hour/100 square feet/year)

Floor type	Range	Percent of rug coverage				
		0-20	20-40	40-60	60-80	80-100
Composition tile	Low	17.6	24.3	33.5	22.6	17.8
	Mean	44.4	34.0	41.6	52.1	21.1
	High	74.4	38.7	49.8	68.3	24.9
Hardwood flooring	Low	8.7	13.6	20.4	16.7	9.0
	Mean	21.8	17.9	34.4	28.2	14.1
	High	25.1	38.5	49.2	38.0	14.7
Carpet	Low	–	–	–	–	10.4
	Mean	–	–	–	–	14.1
	High	–	–	–	–	14.6

[1] Range of average regional values.

Table 10. — Range[1] of average minor maintenance costs (excluding professional carpet cleaning) for living room floors, by type of flooring and rug-coverage area

(In dollars/100 square feet/year)

Floor type	Range	Percent of rug coverage				
		0-20	20-40	40-60	60-80	80-100
Composition tile	Low	0.21	2.13	2.74	0.70	0.48
	Mean	9.89	3.91	3.56	2.17	2.21
	High	21.41	5.64	4.88	3.54	4.63
Hardwood flooring	Low	.85	.62	1.00	.68	1.00
	Mean	4.21	1.32	4.57	1.82	1.90
	High	5.50	1.47	10.46	2.45	2.00
Carpet	Low	—	—	—	—	1.45
	Mean	—	—	—	—	1.63
	High	—	—	—	—	1.99

[1] Range of average regional values.

Appendix B

BASIC ASSUMPTIONS IN CONDUCTING THE STUDY

The main assumption in this study was that the housewife would provide the most objective information about maintenance procedures used, materials required, equipment needed, and when the floors were in need of maintenance to keep them at an acceptable appearance level. If it were possible to conduct the study under controlled conditions, we would have had to define these criteria, and therefore they would have been subjective and subject to bias. Although we eliminated the subjectiveness, we did so at the expense of greater variability. By using housewives' opinions, we did not get the smooth curves obtainable through controlled studies.

The only criteria we specified was a standard of minimum maintenance. We insisted that some method of removing the dust must be performed, that smooth-surface flooring materials must be waxed, and that carpets must be spot-cleaned. How the housewives performed these duties or how often was not specified. In theory then, a housewife may wax smooth-surface floors once a year and never wet-mop, buff, or remove wax buildup. Likewise, she may spot-clean her carpets and never need to shampoo or lift the pile. However, the study showed that most housewives were better homemakers than that.

Another assumption, discussed in the text, was that the apartment housewives would provide maintenance information indicative of that obtained from housewives in a single family home. Although it is possible that housewives in an apartment do not take as good care of their floors as housewives in a single family home, there is no reason to believe they would take better care of one flooring material than another. Therefore the relative differences between flooring materials would remain the same.

Another assumption was that average minor maintenance costs could be determined by combining (1) the information from the housewives on how frequently they performed their various maintenance functions and the types of materials they used with (2) the information from the materials manufacturers on the suggested retail prices of the various materials and the coverage areas they expected from them. The major categories of waxes and wax removers used in calculating minor maintenance costs on smooth-surface floors included (1) solvent-type waxes (liquid, buffable), (2) solvent-type waxes (paste, buffable, including paste wax emulsions), (3) wax emulsions (liquid self-polishing, cleaning, or non-cleaning), and (4) commercial wax removers. The major categories of shampoos and cleaners used for carpets and rugs included (1) liquid shampoos, (2) dry rug cleaners, (3) detergents and other cleaners, which are mixed with water, and (4) commercial spot cleaners.

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